Ontario Geological Survey

Report 221

Geology of the Sturgeon Lake Area

Districts of Thunder Bay and Kenora

By

N.F. Trowell

1983

Ontario

Ministry of
Natural
Resources

Hon. Alan W. Pope
Minister

W.T. Foster
Deputy Minister

© OMNR-OGS 1983
Printed in Canada

Series ISSN 0704-2582
Sub-Series ISBN 0-7743-7356-3

Publications of the Ontario Ministry of Natural Resources are available from the following sources. Orders for publications should be accompanied by cheque or money order payable to the *Treasurer of Ontario*.

Reports, maps, and price lists (personal shopping or mail order):
Public Service Centre, Ministry of Natural Resources
Room 1640, Whitney Block, Queen's Park
Toronto, Ontario M7A 1W3

Reports and accompanying maps (personal shopping):
Ontario Government Bookstore
Main Floor, 880 Bay Street
Toronto, Ontario

Reports and accompanying maps (mail order or telephone orders):
Publications Services Section, Ministry of Government Services
5th Floor, 880 Bay Street
Toronto, Ontario M7A 1N8
Telephone (local calls), 965-6015
Toll-free long distance, 1-800-268-7540
Toll-free from Area Code 807, 0-ZENITH-67200

Every possible effort is made to ensure the accuracy of the information contained in this report, but the Ministry of Natural Resources does not assume any liability for errors that may occur. Source references are included in the report and users may wish to verify critical information.

Part of this publication may be quoted if credit is given. It is recommended that reference to this report be made in the following form:

Trowell, N.F.
1983: Geology of the Sturgeon Lake Area, Districts of Thunder Bay and Kenora; Ontario Geological Survey Report 221, 97p. Accompanied by Maps 2456, 2457, and 2458, scale 1:50 000, 1 Chart, and 1 sheet of Microfiche.

Critical Reader: V.G. Milne
Scientific Editor: Guy Kendrick

1000-100-82-Thorn

FOREWORD

STURGEON LAKE AREA

The Sturgeon Lake Area Metavolcanic-Metasedimentary Belt; internal felsic, intermediate and alkalic intrusions; and adjacent granitic rocks contain deposits of zinc, copper, lead, silver, gold, molybdenum, iron, and fluorite. Mattabi Mines Limited is currently producing from its Zn-Cu-Ag-Pb base-metal sulphide deposit, Sturgeon Lake Mines Limited has exhausted its orebody, and the Lyon Lake and Creek deposits owned by Mattagami Lake Mines Limited await development. A series of detailed mapping projects were initiated in 1968 to provide a more effective base for determining the mineral potential of this region and for guiding exploration. This report presents a compilation of these detailed projects and a regional synthesis and interpretation of the entire area.

E.G. Pye
Director
Ontario Geological Survey

CONTENTS

PAGE
Abstract xi
Introduction 1
- Accessibility 2
- Acknowledgments 2
- Previous Geological Work 2
- Prospecting and Mining Activity 3
- Physiography 5

General Geology 7
- Table of Lithologic Units 6
- Early Precambrian (Archean) 8
  - Metavolcanics and Metasediments 8
    - Metavolcanics 8
      - Mafic to Intermediate Metavolcanics 8
      - Felsic to Intermediate Metavolcanics 9
    - Metasediments 11
      - Clastic Metasediments 11
      - Chemical Metasediments 11
  - Metamorphosed Mafic and Ultramafic Intrusive Rocks 12
  - Felsic, Intermediate, and Alkalic Intrusive Rocks 13
    - Epizonal (Subvolcanic) Intrusions 15
      - Beidelman Bay Pluton 15
      - Shanty Lake Pluton 18
    - Batholithic Granitic Complexes 19
      - Western Granitic Complex 19
      - Eastern Granitic Complex 19
      - Southern Granitic Complex 20
    - Syenite-Monzonite-Granodiorite Plutons 20
      - Vista Lake Complex 22
      - Flindt River Pluton 23
      - Vanessa Lake Pluton 24
      - Beckington Lake East Pluton 24
    - Intrabelt Late Tectonic Granodiorite Intrusions 24
      - Mountain Island Bay Pluton 26
      - Granite Bay Pluton 27
      - Saunders Lake Pluton 27
    - Extra-Belt Trondhjemite-Granodiorite Plutons 27
      - Penassi Lake Pluton 28
      - North Arm Pluton 29
      - St. Anthony Pluton 30
    - Late to Post-Tectonic Quartz Monzonite Plutons 30
      - Valora Lake-Jigger Lake Pluton 30
      - Goodman Lake Pluton 31
    - Alkalic Intrusive Complexes 31
      - Sturgeon Narrows Alkalic Complex 35
      - Squaw Lake Alkalic Complex 36
      - Bell Lake Alkalic Complex 37
    - Age Relationships of the Felsic to Intermediate Intrusive Rocks 38
    - Stratigraphy of the Sturgeon Lake Volcano-Sedimentary Belt 39
      - South Sturgeon Lake Assemblage 39
        - Darkwater Lake Cycle 40
        - Claw Lake Cycle 42
        - Lyon Lake Cycle 43
        - South Shore Cycle 44
        - Petrochemistry of the South Sturgeon Lake Assemblage 47
      - North Sturgeon Lake Assemblage 49
        - Fourbay Lake Cycle 50
        - Jumping Lake-Six Mile Lake Cycle 51

Petrochemistry of the North Sturgeon Lake Assemblage 53
    Northeast Arm Assemblage-Morgan Island Section 61
        North Arm Cycle 61
        Northeast Arm Cycle 61
        Squaw Lake Cycle 63
        Vista Lake Cycle 63
        Vanessa Lake Cycle 64
        Petrochemistry of the Northeast Arm Assemblage-Morgan Island Section 64
    Northeast Arm Assemblage-Beckington Lake Road Section 66
        Beckington Lake West Cycle 66
        Beckington Lake East Cycle 66
        Richan Lake Cycle 67
        Petrochemistry of the Northeast Arm Assemblage-Beckington Lake Road Section 67
    Sturgeon Lake Assemblage 69
        Central Sturgeon Lake-Post Lake Cycle 69
        Petrochemistry of the Sturgeon Lake Assemblage 73

Structural Geology 78
    Folding 78
    Faults 78

Economic Geology 79
    Base-Metal Massive Sulphide Deposits 79
        Copper, Zinc, Silver, and Lead 79
    Gold 81
    Molybdenum 81
    Iron 81
    Fluorite 82
    Radioactive Mineralization 82
    Considerations in Future Exploration 82
        Gold (Silver) 82
        Copper, Zinc, Silver, Lead 83
        Copper, Molybdenum 83

References 85
Index 93

TABLES

Please note that Tables 3 to 24 inclusive are in microfiche in back pocket.

1–Base-metal massive sulphide deposits and gold in the Sturgeon Lake Area 4
2–Table of Lithologic Units 6
3–Chemical analyses of the Beidelman Bay Pluton.
3a–Chemical analyses of the Southern Granitic Batholithic Complex.
5–Chemical analyses of the Vanessa Lake Intrusion.
6–Chemical analyses of the Mountain Island Bay Pluton.
7–Chemical analyses of the Granite Bay Pluton.
8–Chemical analyses of the Penassi Lake Pluton.
9–Chemical analyses of the Goodman Lake Pluton.
10–Chemical analyses of the Bell Lake Complex.
11–Stratigraphy of the South Sturgeon Lake Assemblage.

12–Chemical analyses, South Sturgeon Lake Assemblage, Dark Water Lake Cycle, Sturgeon Lake Area.

13–Chemical analyses of the Claw Lake Cycle: South Sturgeon Lake Assemblage.

14–Chemical analyses, South Sturgeon Lake Assemblage: Lyon Lake Cycle.

15–Chemical analyses of South Sturgeon Lake Assemblage: South Shore Cycle.

15a–Chemical analyses of Metasediments.

16–Chemical analyses of the North Sturgeon Lake Assemblage; Highway 599 Area.

17–Chemical analyses: Northeast Arm Assemblage; Morgan Island Section.

18–Chemical analyses: Beckington West Cycle; Beckington Road Section.

19–Chemical analyses: Central Sturgeon Lake Assemblage; Highway 599 Section.

20–Chemical analyses: Central Sturgeon Lake Assemblage; Mountain Island Section.

21–Chemical analyses: Central Sturgeon Lake Assemblage; Central Section.

22–Further Chemical analyses of the Central Sturgeon Lake Assemblage, Central Section.

23–Chemical analyses of the Central Sturgeon Lake Assemblage, Post Lake Area.

24–Chemical analyses of the Post Lake Ultramafic Rocks.

FIGURES

1–Key map showing location of Sturgeon Lake area x

2–Stratigraphy and Structure of the Sturgeon Lake Volcano-Sedimentary Belt .... Chart A (back pocket)

3–Beidelman Bay Pluton - AFM plot 16

4–Beidelman Bay Pluton - Ol-Ne-Qz plot 17

5–Syenite-Monzonite-Granodiorite Intrusions - AFM plot 21

6–Syenite-Monzonite-Granodiorite Intrusions - Ol-Ne-Qz plot 22

7–Intrabelt Granodiorite Intrusions - AFM plot 25

8–Intrabelt Granodiorite Intrusions - Ol-Ne-Qz plot 26

9–Penassi Lake Pluton - AFM plot 28

10–Penassi Lake Pluton - Ol-Ne-Qz plot 29

11–Goodman Lake Pluton - AFM plot 32

12–Goodman Lake Pluton - Ol-Ne-Qz plot 33

13–Alkali-silica diagram for Alkaline Intrusive Complexes 34

14–Bell Lake Alkaline Complex - Ol-Ne-Qz plot 38

15–Subdivision of the Sturgeon Lake Volcano-Sedimentary Belt showing sample locations . Chart A (back pocket)

16–South Sturgeon Lake Assemblage, Composite AFM plot 48

17–South Sturgeon Lake Assemblage, Composite Cation plot 49

18–North Sturgeon Lake Assemblage, Highway 599 Area - AFM plot 54

19–North Sturgeon Lake Assemblage, Highway 599 Area - Cation plot 55

20–North Sturgeon Lake Assemblage, Samples of Begg's 1-25 - Cation plot 56
21–North Sturgeon Lake Assemblage, Samples of Begg's 25-50 Cation plot 57
22–North Sturgeon Lake Asemblage, Samples of Begg's 51-75 Cation plot 58
23–North Sturgeon Lake Assemblage, Samples of Begg's 76-99 Cation plot 59
24–North Sturgeon Lake Assemblage, Composite Cation plot 60
25–Northeast Arm Assemblage, Morgan Island Section - Composite AFM plot 64
26–Northeast Arm Assemblage, Morgan Island Section - Composite Cation plot 65
27–Northeast Arm Assemblage, Beckington Road Section - Composite AFM plot 68
28–Northeast Arm Assemblage, Beckington Road Section - Composite Cation plot 69
29–Central Sturgeon Lake Assemblage, Composite AFM plot 74
30–Central Sturgeon Lake Assemblage - Composite Cation plot 75
31–Central Sturgeon Lake Assemblage - Ultramafic Intrusions CaO-MgO-Al_2O_3 plot 76
32–Central Sturgeon Lake Assemblage - Mafic and Ultramafic Intrusions - Cation plot 77

GEOLOGICAL MAPS

(back pocket)

Map 2456–North Arm of Sturgeon Lake,
Districts of Kenora and Thunder Bay.
Scale 1:50 000.

Map 2457–Sturgeon Narrows,
Districts of Kenora and Thunder Bay.
Scale 1:50 000.

Map 2458–Whiterock Lake,
District of Kenora.
Scale 1:50 000.

CHART

Chart A–Figures 2, and 15.

MICROFICHE

Tables 3 to 24 inclusive.

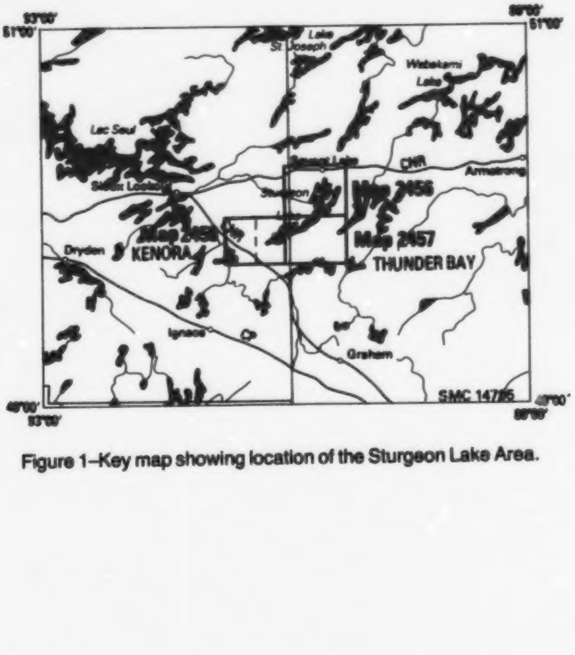
93°00'
51°00'
89°00'
51°00'
Lake
St. Joseph
Wabakimi
Lake
Lac Seul
Savant Lake
CNR
Armstrong
Sioux Lookout
Sturgeon
Map 2456
Map 2458
KENORA
Dryden
Map 2457
THUNDER BAY
Ignace
CP
Graham
SMC 14785
49°00'
93°00'
49°00'
89°00'

Figure 1–Key map showing location of the Sturgeon Lake Area.

ABSTRACT

This report describes the geology and mineralization of the Sturgeon Lake area. The area, situated 76 km east of Sioux Lookout, comprises an area of 2700 km^2 within the Wabigoon Subprovince of the Precambrian Shield.

The bedrock in the area is Precambrian in age. The stratigraphic succession has been subdivided into four assemblages on the basis of lithology and geographic distribution. These assemblages comprise several volcanic cycles. Each of these cycles consists of a lower unit of mafic metavolcanics and an upper unit of intermediate to felsic, generally fragmental metavolcanics. A change in chemistry, an hiatus in volcanism, or a period of sedimentation demarcate cycle and assemblage boundaries. Two major episodes of clastic sedimentation have occurred in the area. Interbedded sulphidic and graphitic ironstone and mudstone are associated with intermediate to felsic metavolcanics. Interbedded chert and silicate-quartz-magnetite ironstone are found associated with clastic metasedimentary sequences.

Subvolcanic gabbroic and ultramafic intrusions occur dominantly in lower mafic metavolcanics, but extensively intrude felsic to intermediate fragmentals and clastic metasediments. Epizonal felsic intrusions in the southern part of the area are interpreted to be of subvolcanic origin.

Batholithic granitic complexes composed predominantly of trondhjemite and granodiorite define the southern, eastern, and northwestern boundaries of the volcano-sedimentary belt. Syn- to late tectonic plutons of granodiorite and trondhjemite occur marginal to and intrude into the volcano-sedimentary belt. Syenite-monzonite granodiorite plutons emplaced within the mafic metavolcanic-metasedimentary succession marginal to the Eastern Granitic Batholithic Complex may be anatectic in origin. Late to post tectonic quartz monzonite stocks and alkalic intrusive complexes were emplaced marginal to and within the confines of the volcano-sedimentary belt.

The metavolcanics, metasediments, mafic and ultramafic intrusions, and felsic epizonal intrusions were metamorphosed to the greenschist to lower almandine-amphibolite facies rank of metamorphism.

The major structures consist of two synclinal folds trending east and north-west-northeast respectively. The Sturgeon Narrows Cataclastic Zone transects the volcano-sedimentary belt, and is almost 50 km long.

The St. Anthony Mine operated intermittently from 1905 to 1941 and produced 63 310 ounces of gold and 16 341 ounces of silver.

Mattabi Mines Limited and Sturgeon Lake Mines Limited are presently producing from their respective Zn-Cu-Ag-Pb base-metal sulphide deposits. The Lyon Lake and Creek deposits (owned by Mattagami Lake Mines Limited) await development.

Geology of the Sturgeon Lake Area, Districts of Thunder Bay and Kenora, by N.F. Trowell, Ontario Geological Survey Report 221, 97p. Published 1983. ISBN 0-7743-7356-3.

CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

If the reader wishes to convert imperial units to SI (metric) units or SI units to imperial units the following multipliers should be used:

CONVERSION FROM SI TO IMPERIAL			CONVERSION FROM IMPERIAL TO SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy)/ton (short)	20.0	pennyweights/ton (short)
1 pennyweight/ton (short)	0.05	ounce (troy)/ton (short)

NOTE–Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries published by The Mining Association of Canada in co-operation with the Coal Association of Canada.

Geology
of the
Sturgeon Lake Area
Districts of Thunder Bay and Kenora

By

N.F. Trowell[1]

INTRODUCTION

The Sturgeon Lake area is situated 76 km east of Sioux Lookout, Ontario and is bounded by Latitudes 49°45′ and 50°15′N and Longitudes 90°28′ and 91°00′W (North Half) and 90°30′ and 91°30′W (South Half). The area covers about 2700 km^2 and is within the Districts of Thunder Bay and Kenora and the Patricia and Kenora Mining Divisions.

This report represents a synopsis of the author's past work in the area (Trowell 1970, 1974a, 1974b, 1976, 1977, 1978) plus new geological information gathered during the field seasons of 1975 and 1976. Additional sources of information used in the preparation of this report are: (1) the assessment files of the Assessment Files Research Office, Ontario Geological Survey, Toronto; (2) Ontario Geological Survey-Geological Survey of Canada aeromagnetic and radiometric maps; (3) Ontario Geological Survey ground magnetic and gravimetric maps; (4) Ontario Geological Survey Data Series Maps; (5) Ontario Geological Survey and Geological Survey of Canada geological maps and reports; (6) scientific publications pertinent to the area; and (7) unpublished dissertations.

R.P. Sage[2] carried out a petrochemical study of the Sturgeon Narrows and Squaw Lake Alkalic Complexes during the summer of 1976. Data from this study are incorporated within this report.

---

[1] Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.

[2] Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.

Manuscript approved for publication by the Chief Geologist, January 16, 1980.
This report is published with the permission of E.G. Pye, Director, Ontario Geological Survey.

Geological mapping was done at a scale of 1:15 840 and 1:31 680 for publication at 1:50 000. The Cartographic Section, Ontario Division of Lands, Ministry of Natural Resources prepared the cronaflex base maps. Final coloured geological maps, Maps 2456, 2457, and 2458 at a scale of 1:50 000, are in the back pocket.

Accessibility

Highway 599 extends through the western part of the area and provides access to Sturgeon Lake. Highway 642 extends from Highway 599 to Sioux Lookout. The Canadian National railway line defines the northern border of the map-area. Mine-access roads provide access to the area south of Sturgeon Lake. A recently constructed lumber road crosses the northern part of the area. Much of the eastern part of the area can be reached by portages from Sturgeon Lake. Float-equipped aircraft provide access to the southeastern part of the area.

Acknowledgments

The author was assisted during the 1976 field season by Messrs. John Carter and Paul McCarter. Mr. McCarter, as senior assistant, carried out independent mapping of selected areas.

Previous Geological and Geophysical Work

W. McInnes (1900) of the Geological Survey of Canada was presumably the first geologist to map in the Sturgeon Lake area. E.S. Davidson (1901) described the area in Survey Number 9 in the Report of the Survey and Exploration of Northern Ontario in 1900. A.P. Coleman (1902) in his report on the iron ranges of Northwestern Ontario reported on some of the gold prospects on Sturgeon Lake. W.G. Miller (1903) described the workings on many of the claims on Sturgeon Lake. W.H. Collins (1907) mapped the area between Lake Nipigon and Sturgeon Lake.

Early exploration activity *circa* 1901 to 1942, with specific references to the St. Anthony Mine, was described by W.E.H. Carter, E.T. Corkill, T.F. Sutherland *et al.*, D.G. Sinclair *et al.* and W.O. Tower *et al.* A complete list of references to these individuals' reports is given in N.F. Trowell's (1977)report.

T.L. Gledhill (1924), A.R. Graham (1930), and H.C. Horwood (1937a) gave fairly detailed descriptions of the geology of the general Sturgeon Lake area. T.L. Tanton (1940), D.P. Rodgers (1964), and R. Skinner (1969) have given the most recent descriptions of the Sturgeon Lake area. F.J. Pettijohn (1937) made brief mention to the Sturgeon Lake area in his discussion of the Northern Subprovince of the Lake Superior region.

The map-area was surveyed aeromagnetically in 1961, and map sheets at a scale of 1:63 360 covering this area have been jointly released by the Geological Survey of Canada and the Ontario Geological Survey (Ontario Department of Mines-Geological Survey of Canada 1961a, 1961b, 1961c, 1961d). Staff of the Ontario Geological Survey have conducted detailed ground magnetometer surveys (Barlow 1974a, 1974b, 1975a and c) and a ground gravimetric survey (Barlow 1975b) in the area. Airborne radiometric surveys also cover the area (Ontario Department of Mines-Geological Survey of Canada 1976a and b).

Data Series maps prepared by the Resident Geologist and staff, Ontario Ministry of Natural Resources, Sioux Lookout, provide coverage for most of the report-area (Palonen and Speed, 1975a, 1975b, 1975c, 1975d, 1977; Palonen *et al.* 1976).

Several papers, studies, and theses have been written on more specific geological, geophysical, and economic geology topics within the area. Special note should be made of the excellent work of the following authors; J.M. Franklin (1975, 1976, 1977), J.M. Franklin, Gibb, *et al.* (1973, 1977); J.M. Franklin, Kasarda, and Poulsen (1975); R.S. Shegelski (1975, 1976, 1978); R.S. Shegelski and R.T. Bell (1976); and D.G. Beggs (1975). Further pertinent papers, studies, and theses are referred to throughout this report.

Prospecting and Mining Activity

Gold, zinc, copper, silver, molybdenum, iron, fluorite, and radioactive mineralization have been reported in the area.

W. McInnes (1900, p.115A-122A) reported that gold-bearing quartz veins were discovered on Sturgeon Lake, in the summer of 1898, by a prospector named Peter King, and that a number of claims were staked. Intermittent exploration for gold was carried out during the next few years. The construction in 1909 of the Lake Superior Branch of the Grand Trunk Pacific Railway, and the establishment of steamer lines on Sturgeon Lake to facilitate transportation of materials for railway construction, resulted in increased, but temporary exploration activity.

During the period 1905 to 1941, the St. Anthony Mine (Table 1) produced 63 310 ounces of gold and 16 341 ounces of silver.

Other minor gold occurrences in the area have been tested by exploratory shafts, adits, pits, and trenches. These occurrences are generally associated with quartz veins in mafic metavolcanics or epizonal subvolcanic felsic intrusions (Darkwater Mine). Other lithologic associations in which gold has been reported include sulphide ironstone and trondhjemite dikes. Minor pyrite, pyrrhotite, chalcopyrite, galena, and sphalerite occur in the gold-bearing quartz veins.

A surge of exploration activity began in 1969-1970 following the discovery, in October 1969, by the Exploration Division of Mattagami Lake Mines Limited of a base-metal sulphide deposit (Mattabi Mines Limited) on Block Number 7 of the Abitibi Paper Company Limited. Exploration continued with the further discovery of new base-metal deposits (Table 1).

Franklin and Gibb *et al.* (1977) summarized the history of exploration for

TABLE 1 BASE-METAL MASSIVE SULPHIDE (DATA FROM FRANKLIN, J. M., GIBB, W., POULSEN, K. H., AND SEVERIN, P., 1977) DEPOSITS AND PAST GOLD PRODUCER IN THE STURGEON LAKE AREA.

OWNER	DEPOSIT NAME	DISCOVERY DATE	DEPOSIT TYPE	CURRENT TONNAGE ESTIMATE (TONS)	Zn %	Cu %	Pb %	Ag oz ton	Au oz/ton
Mattabi Mines Limited	Mattabi	September/1969	Zn-Cu-Ag-Pb-(Au)	*** 13,665,800	7.5	0.8	0.77	3.10	–
Sturgeon Lake Mines Limited	Boundary	October/1970	Zn-Cu-Ag-Pb	*** 2,110,584	10.64	2.98	1.47	6.14	0.021
Mattagimi Lake Mines Limited	Lyon Lake Creek	October/1971 February/1972	Zn-Cu-Ag-Pb	*** 4,029,500	6.66	1.15	0.63	3.30	–
Can-Con Enterprises & Exploration Limited	St. Anthony *	1901-1941	Au-Ag	** 331,069 (milled)	–	–	–	–	0.19/ton milled

* Past Producer

** From 1905 to 1941, gold and silver valued at $2,157,823 and $7,469 respectively were produced. (Ontario Department of Mines and Northern Affairs, Mineral Resources Circular Number 13, Gold Deposits of Ontario by S. A. Ferguson, H. A. Groen, and R. Haynes, 1971)

*** All tonnage estimates are preproduction estimates. (Franklin and Gibb *et al.* 1977).

and development of these deposits:

The Mattabi deposit was first located by ground geophysical follow-up to an anomaly indicated on an airborne Input Survey. Subsequent diamond-drilling outlined a massive sulphide deposit with a length of 1800 feet and a maximum width of 300 feet. The deposit has a distinctive EM and magnetic anomaly. The pre-production ore reserves were 13 665 800 tons with an average grade of 7.5 percent zinc, 0.8 percent copper, 0.77 percent lead, and 3.10 ounces per ton of silver. Since 1972 the deposit has been mined from an open pit. Underground development work began in 1975.

In 1970, Falconbridge Nickel Mines Limited, testing an induced polarization anomaly, discovered a massive sulphide orebody on claims optioned from New Brunswick Uranium Metals and Mining Limited. Sturgeon Lake Mines Limited is a joint venture company involving Falconbridge Copper Limited, N.B.U. Mines Limited, and Sturgeon Lake Mines Limited.

Pre-production ore reserves were 2 110 584 tons grading 2.98 percent Cu, 10.64 percent Zn, 1.47 percent Pb, 6.14 ounces of Ag per ton, and 0.021 ounce of Au per ton.

The mine (open pit) started production in March, 1974 and production was stockpiled near the crusher until milling commenced in September, 1974. The mill is currently operating at a rate of 1200 tons per day. During 1971 and 1972, the Lyon Lake and Creek Zone deposits, containing 4 029 500 tons of ore grading 6.66 percent zinc, 1.15 percent copper, 0.63 percent lead, and 3.30 ounces of Ag per ton, were discovered. The deposits mentioned have a poor geophysical expression, and were located by drilling after determining stratigraphic controls.

Copper and molybdenum of porphyry copper affinity are found in the Beidelman Bay Pluton. Substantial amounts of chalcopyrite are present, but average grade is at present sub-economic.

Iron occurs in sulphidic, locally graphitic, and quartz-magnetite ironstone situated respectively, within metavolcanics and metasediments. Interpretation of the ground magnetic data (Barlow 1975c) suggested that substantial iron in the form of magnetite is present in the ironstones that underlie Sturgeon Lake. These ironstones are, however, too deeply buried to be amenable to mining operations currently in use.

Fluorite is found disseminated throughout the Sturgeon Narrows Alkalic Complex, but no concentrations have as yet been located.

Spot occurrences of radioactive mineralization are present in breccia zones along Sturgeon Narrows.

Physiography

Sturgeon Lake is 409.0 m above sea level and the maximum topographic relief is about 60 m. The relief is dominantly controlled by the distribution of Pleistocene and Recent deposits, and is partly controlled by the differential erosion of contrasting lithologies and by structures.

In the northeastern part of the area, the contact between the metavolcanic-metasedimentary belt and the Eastern Granitic Complex is a drainage divide separating two major drainage basins. The waters to the west of this divide flow into the Sturgeon River, part of the English River Drainage Basin, and eventually flow into Lake Winnipeg. The waters to the east of the divide drain into the Albany River, part of the Albany River Drainage Basin, and eventually flow into James Bay.

Bedrock exposure is sparse to moderately abundant. It is generally moss-covered with the exception of shoreline exposures and some road exposures.

TABLE 2 TABLE OF LITHOLOGIC UNITS FOR THE STURGEON LAKE AREA.

PHANEROZOIC

CENOZOIC

Quaternary

PLEISTOCENE AND RECENT

Glacial deposits; lake, swamp, and stream deposits.

Unconformity

PRECAMBRIAN

EARLY PRECAMBRIAN (ARCHEAN)

Felsic, Intermediate, and Alkalic Intrusive Rocks

SQUAW LAKE ALKALIC COMPLEX

Syenite; lamprophyre dikes; hybrid syenite; xenolithic syenite; monzonite, monzosyenite; pegmatite; syenite sills and dikes.

STURGEON NARROWS ALKALIC COMPLEX

Syenite; lamprophyre dikes; porphyry, pegmatite, aplite and feldspathic dikes; xenolithic syenite; syenodiorite; syenogabbro; xenolithic syenodiorite, syenogabbro; carbonate breccia; porphyroblastic syenite, syenodiorite; banded syenite.

BELL LAKE ALKALIC COMPLEX

Biotite-hornblende-augite monzonite, syenite; porphyritic biotite-hornblende-augite monzonite, syenite; porphyritic perthite monzonite, syenite; xenolithic monzonite, syenite; lamprophyre dikes; gabbro; aplite, syenite pegmatite.

QUARTZ MONZONITE INTRUSIONS

Quartz monzonite, granodiorite; xenolithic/hybrid quartz monzonite, granodiorite; granodiorite, quartz monzonite dikes.

MONZONITE-SYENITE-GRANODIORITE INTRUSIONS

Amphibole, biotite-amphibole granodiorite, monzonite, syenite; porphyritic amphibole, biotite-amphibole, granodiorite, monzonite, syenite; xenolithic/hybrid granodiorite, monzonite, syenodiorite; pegmatite; leucocratic granodiorite, quartz monzonite.

TRONDHJEMITE-GRANODIORITE INTRUSIONS

Foliated granodiorite, trondhjemite; trondhjemite; porphyritic trondhjemite, granodiorite; muscovite granodiorite, trondhjemite; xenolithic granodiorite, trondhjemite.

BATHOLITHIC GRANITIC COMPLEXES

Biotite-hornblende, hornblende-biotite trondhjemite; porphyritic foliated granodiorite, trondhjemite; foliated granodiorite; foliated quartz monzonite; porphyritic quartz monzonite, granodiorite; massive trondhjemite; porphyritic trondhjemite, granodiorite; quartz-lenticule granodiorite, trondhjemite; xenolithic hybrid granodiorite, trondhjemite, quartz monzonite; pegmatite, aplite.

EPIZONAL (SUBVOLCANIC) INTRUSIONS

Trondhjemite, granodiorite; porphyritic trondhjemite, feldspar porphyry, quartz-feldspar porphyry; quartz diorite; xenolithic trondhjemite, granodiorite; quartz-tourmaline-ankerite veins, quartz veins.

MAFIC AND ULTRAMAFIC INTRUSIVE ROCKS

Gabbro, diorite; porphyritic gabbro, diorite; anorthositic gabbro, diorite; serpentinized peridotite.

METASEDIMENTS

Wacke; arenite, arkose; siltstone, argillite mudstone; conglomerate; debris flow/conglomerate; quartz-magnetite ironstone; sulphide (graphitic) ironstone.

METAVOLCANICS

FELSIC TO INTERMEDIATE METAVOLCANICS

Tuff, lapilli-tuff; lapilli-tuff, lapillistone tuff; lapillistone tuff, tuff breccia, pyroclastic breccia, tuff breccia/conglomerate; quartz porphyry, quartz-feldspar porphyry, feldspar porphyry; felsite; schists, gneisses.

MAFIC METAVOLCANICS

Massive flows; porphyritic flows; pillowed flows; amygdaloidal/vesicular flows; autoclastic breccia, hyaloclastic breccia; pyroclastics, re-deposited fragmentals.

GENERAL GEOLOGY

The Sturgeon Lake area is a part of the Wabigoon Subprovince of the Superior Province (Goodwin 1970; Mackasey *et al.* 1974). The rocks are Precambrian in age, and are partly covered by Pleistocene and Recent deposits.

The author has subdivided the Sturgeon Lake Metavolcanic-Metasedimentary Belt into four assemblages on the basis of lithology and geographic distribution. These are:

(1) the South Sturgeon Lake Assemblage;
(2) the North Sturgeon Lake Assemblage;
(3) the Northeast Arm-Beckington Lake Assemblage;
(4) the Sturgeon Lake Assemblage (*see* Figure 2, Chart A, back pocket).

The assemblages are subdivided into volcanic cycles. A volcanic cycle is herein defined as: 1) those rocks deposited during a period of volcanism marked by a change from a predominantly mafic to a predominantly felsic composition, by a change in the chemical rock suite or by a hiatus in volcanism with or without concomitant sedimentation.

Cycles were further subdivided into informal formations. These are designated alphabetically due to the tentative nature of the stratigraphy. Even though the lithologies are heterogeneous, one or two of them predominate in each formation. Individual formations are locally continuous and can be about several kilometres to several tens of kilometres in length. Boundaries are transitional, difficult to sharply define, and subject to change.

In this report, the following lithological, chemical, and metamorphic classifications are followed:

(1) Sedimentary rocks are classified following G.M. Young (1967),
(2) Pyroclastic rocks are classified after R.V. Fisher (1966),
(3) Intrusive rocks are classified after L.D. Ayres (1972),
(4) Volcanic rocks are classified chemically according to T.N. Irvine and W.R.A. Baragar (1971) and L.S. Jensen (1976). The terminology for rock types and magma series is taken from Jensen (1976). AFM plots (Irvine and Baragar 1971) are presented for comparison.

(5) Alkalic intrusive rocks are classified chemically according to K.L. Currie (1976),
(6) Metamorphic assemblages and facies terminology are used according to F.J. Turner (1968).

Early Precambrian (Archean)

METAVOLCANICS AND METASEDIMENTS

Metavolcanics

The metavolcanic rock classification in this report is based upon field criteria supplemented by petrographic examination.

These rocks are classified on a two-fold subdivision as follows: mafic rocks, and mafic to intermediate rocks (more than 35 percent mafic minerals), and felsic to intermediate rocks (less than 35 percent mafic minerals and generally less than 25 percent mafic minerals).

The chemical data tend to support this two-fold subdivision, showing a preponderance of basalt with minor andesite representing the mafic division, and rhyolite and dacite representing the felsic to intermediate division [see Cation Plots, Jensen (1976), this report]. The data also indicate that some units belong to the mafic rather than the felsic to intermediate subdivision as they were previously mapped by the author. Figure 15 (Chart A, back pocket) gives the location of samples that have been chemically analyzed. Begg's(1975) sample locations are indicated by the dots in the Six Mile Lake area, namely in the squares I8, J8, I7, J7, and the parts of I6 and J6 north of Sturgeon Lake.

MAFIC TO INTERMEDIATE METAVOLCANICS

Mafic to intermediate metavolcanics compose the dominant lithology in the map-area. These rocks occur at several stratigraphic levels and generally compose the lower part of individual volcanic cycles.

These rocks generally weather to various shades of green and grey. Fresh surfaces have similar colours, but have darker hues. White and brown hues are a consequence of carbonitization. Dark green to black metavolcanics reflect the development of hornblende formed under almandine-amphibolite facies conditions.

Recrystallization is prevalent, but pilotaxitic, subophitic to ophitic, and rare isogranular relict textures are locally preserved in weakly deformed rocks.

The metavolcanics are variably massive, foliated, and schistose. Banding in metavolcanics marginal to the batholithic complexes is due to the accentuation of primary bedding features of tuffaceous members or to metamorphic differentiation accompanying deformation.

The mafic to intermediate metavolcanics consist of the following mineral assemblages: (1) plagioclase (albite-oligoclase) + tremolite-actinolite + quartz ± chlorite ± chloritoid (uncommon) ± biotite ± epidote ± carbonate ± white mica for rocks of the greenschist facies rank and (2) plagioclase (oligoclase-andesine) + hornblende ± anthophyllite ± quartz ± biotite ± clinopyroxene ± garnet ± epidote ± zoisite ± carbonate for rocks of the almandine-amphibolite facies rank. Accessories include iron-titanium oxides, sphene, apatite, pyrite, pyrrhotite, and uncommon chalcopyrite. Retrograde zeolites were noted in rocks of the far northern part of the map-area.

For this report, volcanic rocks have been subdivided on the basis of flow features and textures into the following types: massive flows, porphyritic flows, pillowed flows, amygdaloidal/vesicular flows, pyroclastic rocks, and autoclastic/hyaloclastic breccias.

Massive flows comprise both fine- to medium-grained and medium- to coarse-grained units. The coarse-grained varieties could represent either coarse flow centres or synvolcanic intrusive sills.

Porphyritic flows or flow zones contain feldspar phenocrysts visible in hand specimen. Porphyritic flows, are not widespread, but do appear to occur at specific stratigraphic intervals.

Pillowed flows are common. Specific attention was paid to the size and shape of the pillows, selvage thicknesses, and vesicularity. This is in an attempt to relate discrete pillowed units to mode and environment of deposition, and if possible, to chemical composition.

Vesicular and amygdaloidal flows commonly are pillowed. Vesicularity is thought to be primarily a function of water depth and chemical composition. Changes in vesicularity through stratigraphic intervals were used to interpret environments of deposition.

Mafic to intermediate pyroclastics and redeposited fragmental rocks are noticeably abundant towards the base of the South Sturgeon Lake Assemblage. These fragmental rocks are heterolithic; the matrix is mafic to intermediate, and the clasts are predominantly felsic in composition. In this report, classification of fragmental rocks into either mafic to intermediate or felsic to intermediate rocks refers to the composition of the matrix.

Autoclastic and hyaloclastic breccias locally comprise the top, and more rarely, the bottom zones of flows. These zones are similar to the porphyritic flows and occur at specific stratigraphic intervals. The autoclastic and hyaloclastic breccia zones are not common.

The occurrence of varioles were not recorded except at one or two occurrences (not shown on Map 2457, back pocket) in the upper cycles of the South Sturgeon Lake Assemblage.

FELSIC TO INTERMEDIATE METAVOLCANICS

Felsic to intermediate metavolcanics occur at several stratigraphic intervals within the four assemblages. These rocks consist predominantly of pyroclastic and redeposited fragmental rocks. Autoclastic breccias characterized by monolithic fragments and a high fragment to matrix ratio occur locally. No unequivocal flows were found, but synvolcanic intrusive equivalents are common. Rare spherulitic units are similarly fragmental.

These rocks are dominantly tuff and lapilli-tuff, and contain local accumulations of tuff-breccia and rarely pyroclastic breccia. Crystal and lithic varieties occur in these rocks.

These rocks were originally formed by explosive volcanic activity and by auto-brecciation of extrusive domes or flows. The unconsolidated fragmentals were deposited or redeposited by a debris flow mechanism. Debris flows deposited generally unstratified, unsorted and ungraded lensoid accumulations of variably-sized fragmental rocks. Such rocks compose the majority of the Darkwater Lake Cycle, South Sturgeon Lake Assemblage (see this report). Turbidity flows, a specific type of debris flow, deposited the fragmental rocks along the Northeast Arm and westwards in the Six Mile Lake area. These rocks are similar to the subaqueous pyroclastic flows, described by R.S. Fiske (1963a, 1963b) and R.S. Fiske and T. Matasuda (1964). The units just described exhibit such features as bedding, grading, some sorting, and rare scours and ripples.

Normal and reverse grading, scour channels, and bedding features comparable to Bouma sequences, but of an order of magnitude higher, suggest that the fragmental rocks of the South Shore Cycle were redeposited similarly to the conglomerates of the redeposited turbidite-conglomerate association (Walker 1975).

Features such as the presence of pumice and fiamme, similar to those observed in ignimbrites were reported on by Franklin and Gibb *et al.* (1977). The lack of unequivocal vapour phase recrystallization features such as axiolitic structures does, however, make an interpretation of subaerial volcanism somewhat tenuous.

These rocks exhibit recrystallized granoblastic-polygonal to porphyritic textures. The mineralogy indicates these rocks have been metamorphosed from the low greenschist to lower almandine-amphibolite facies rank. A zone of felsic to intermediate fragmental rocks that extends from the Northeast Arm of Sturgeon Lake northwards into Boucher Township (Trowell 1978) well illustrates this transition in metamorphic grade.

In rocks exposed in the Northeast Arm area, the metamorphic mineral assemblage comprises: quartz + plagioclase (albite) + muscovite ± microcline (rare) + chlorite ± chloritoid ± actinolite (minor) ± stilpnomelane, and is characteristic of the greenschist facies, chlorite subfacies assemblage. At the northern end of Sturgeon Lake mineralogy characteristic of the biotite-chlorite subfacies, greenschist facies occurs: quartz + plagioclase (albite-oligoclase) + muscovite ± microcline ± biotite ± chlorite ± garnet, and ± actinolite. East of Ouilette Lake, staurolite and chloritoid are found accompanying biotite ± garnet. Chloritoid then disappears, and staurolite characterizes this zone to an area just north of the railway tracks where andalusite appears accompanying the staurolite. Further to the north, outside the map-area (Trowell 1978), cordierite, then kyanite, and finally sillimanite appear, and mark the transition from high greenschist to low almandine-amphibolite facies rank respectively. Plagioclase compositions become increasingly calcic until almost pure anorthite occurs in the highest grade zone. Complexities, however, exist. The northern metamorphic mineral assemblages are disequilibrium assemblages, and as well, evidence exists of more than one period of metamorphism, both prograde and retrograde, and of metasomatism. Accessories include myrmekite, carbonate, epidote, zeolites, opaque oxides, sulphide minerals, zircon, sphene, tourmaline, rutile, and talc.

These rocks are variably massive, and are weakly foliated to strongly foliated. Non-penetrative shearing has transformed them to quartz-sericite schist and phyllite. The fresh and weathered surfaces are various shades of pink, green, grey, yellow, and brown.

Metasediments

CLASTIC METASEDIMENTS

Clastic metasediments comprise sandstone, mudstone, and debris flow deposits and conglomerate. Wacke is the dominant variety of sandstone, but arkose does occur in the East Bay and Sturgeon Narrows metasedimentary sequences. Siltstone and mudstone are prevalent in the turbidites of the Princess Lake-Quest Lake area. Debris flow deposits and conglomerate of the turbidite and possibly shallow water alluvial fan (East Bay-Sturgeon Narrows metasediments) association form lensoid accumulations within the various metasedimentary sequences. These accumulations contain pebble- to cobble-sized polymictic volcanic clasts. The rocks are generally poorly sorted, unstratified, and rarely graded. The granitoid pebbles and cobbles in the conglomerate units exposed in the southern part of Sturgeon Lake and the coarse blue quartz grains in the East Bay arkoses are similar in composition and/or texture to, and were possibly derived by erosion respectively of, synvolcanic and syn- to late tectonic marginal trondhjemite-granodiorite intrusions.

In addition to the lithic component, the mineral assemblages of the metasediments are: (1) quartz + plagioclase (albite-oligoclase) ± alkali feldspar (minor) ± muscovite + chlorite ± amphibole (tremolite-actinolite) + carbonate ± epidote ± biotite for metasediments metamorphosed to the greenschist facies rank; and (2) quartz + plagioclase (albite-oligoclase) ± amphibole (tremolite-actinolite, hornblende) ± biotite ± muscovite ± alkali feldspar (rare) ± garnet + carbonate ± epidote for metasediments metamorphosed to the lower almandine-amphibolite facies rank. Aluminosilicates including staurolite and andalusite occur in metasediments transitional from the upper greenschist to the lower almandine-amphibolite facies rank of metamorphism. Accessories include iron-titanium oxide, magnetite, pyrite, pyrrhotite, graphite, sphene, zircon, and hematite.

CHEMICAL METASEDIMENTS

Chemical metasediments comprise interbedded chert with quartz-magnetite, and mudstone with sulphide and graphitic ironstones. Carbonate minerals are common in the ironstone units and also, a silicate component, hornblende, is present within the eastward extension of the quartz-magnetite ironstone units of the South Sturgeon Lake Assemblage.

In the past, ironstones have been assigned to facies. Sulphide and oxide facies are two examples. The designation was dependent upon which iron-bearing minerals were present. Interpretations pertaining to environments of deposition were based upon the facies of ironstone present (James 1954; Goodwin 1973). This concept is questionable, for, as pointed out by E. Dimroth (1977), the physiochemical conditions prevailing in the depositional zone determine the final mineral component prior to metamorphism of these units. For example, Shegelski (1978) has shown that some of the sulphidic and graphitic ironstone in the South Sturgeon Lake Assemblage were apparently deposited under relatively shallow water conditions. Similarly, the quartz-magnetite ironstone units situated in the upper metasedimentary sequence of the South Sturgeon Lake Assemblage are found in association with wacke-siltstone apparently of the deep-water turbidite association.

METAMORPHOSED MAFIC AND ULTRAMAFIC INTRUSIVE ROCKS

Four main groupings of mafic intrusions have been established and are based upon time of emplacement and composition.

One group comprises synvolcanic intrusions emplaced within mafic to intermediate metavolcanic sequences. Sills predominate, but dikes, sometimes feeding sills and flows, are also present. Textures vary from fine to coarse grained, and from equigranular to porphyritic. Compositions are similar to effusive equivalents. Ages and sequences of mafic to intermediate metavolcanics are different, and ages and sequences of mafic intrusions are correspondingly different .

The second group of intrusions are possibly comagmatic with upper mafic metavolcanic sequences; but they are emplaced in lower felsic to intermediate metavolcanic sequences. Within the map-area, a major suite of these intrusions occurs within the North Sturgeon Lake and Northeast Arm Assemblages. Equigranular and porphyritic (plagioclase) gabbro and diorite predominate. Characteristic of this suite, however, is anorthositic gabbro-diorite that occurs as phases of the gabbro and diorite, and as discrete intrusions. These anorthositic intrusions exhibit both cumulate (sill-like) and laminar flow segregation (dike-like) features. It should be noted that the upper mafic metavolcanic sequences are not feldspar porphyritic. These sequences may be comagmatic to the intrusions, and their bulk composition as compared with that of the intrusions will be different due to the segregation of cumulate feldspar in the intrusions.

Large subcircular to elliptical multi-phase stocks compose the third variety. The composition of these stocks ranges from ultramafic (pyroxenite) to quartz-amphibole-plagioclase pegmatite differentiates. These bodies occur in the Watcomb map-area (Trowell 1970), where they intrude basal mafic metavolcanics of the South Sturgeon Lake Assemblage. The author interpreted these bodies to be subvolcanic intrusions or solidified high-level magma chambers that fed upper mafic to intermediate flows and synvolcanic intrusion sequences.

Gabbros of high-magnesian tholeiitic affinity form a fourth variety (Jensen 1976) that occurs as differentiates (Zalnierinunas 1978) of the ultramafic intrusions of the Sturgeon Lake Assemblage.

Criteria for distinguishing these intrusions from flows include these features: directly observable intrusive relationships; grain size with the intrusions generally, though not always, coarser than the flows; internal structure with the intrusions being generally massive to weakly foliated, often with well-developed joint sets; and a characteristic aeromagnetic expression, topographic expression, mineralogy, and texture. All these features are commonly different from those for the associated flows.

Textures vary from equigranular ophitic to subophitic and porphyritic to glomeroporphyritic. Plagioclase feldspar is the common phenocryst, but locally amphibole alone and amphibole with plagioclase phenocrysts are present. Amphibole, in most cases, appears secondary after pyroxene, but in some intrusions, it could be a primary crystallizing phase.

These intrusions have been metamorphosed to the same rank as the associated mafic to intermediate metavolcanics. Metamorphic mineral assemblages are also similar to those of the associated flows, but relict pyroxene and calcic plagioclase are locally preserved in the interiors of the larger intrusions.

Ultramafic intrusions outcrop on Mountain Island and north of Barge and Post Lakes. These intrusions have been emplaced at the contact between lower mafic metavolcanic flows and upper intermediate to locally felsic pyroclastic rocks. A more complete description is given in the discussion of the Sturgeon Lake Assemblage; see appropriate description in section on "Stratigraphy of the Sturgeon Lake Volcano-Sedimentary Belt".

FELSIC, INTERMEDIATE, AND ALKALIC INTRUSIVE ROCKS

On the basis of mineralogical and chemical composition, relative age, and spatial distribution, a number of distinct varieties of felsic to intermediate rocks have been recognized. For the present discussion they are divided into the following:

1) EPIZONAL (SUBVOLCANIC) INTRUSIONS

i) Beidelman Bay Pluton.

ii) Shanty Lake Pluton.

2) BATHOLITHIC GRANITIC COMPLEXES

i) Southern Granitic Complex.

ii) Eastern Granitic Complex.

iii) Western Granitic Complex.

3) SYNTECTONIC SYENITE-MONZONITE-GRANODIORITE INTRUSIONS

i) Vista Lake Complex.

ii) Flindt River Pluton.

iii) Vanessa Lake Pluton.

iv) Beckington Lake East Pluton.

4) INTRABELT SYN- TO LATE-TECTONIC GRANODIORITE INTRUSIONS

i) Mountain Island Bay Pluton.

ii) Granite Bay Pluton.

iii) Saunders Lake Pluton.

5) EXTRABELT TRONDHJEMITE-GRANODIORITE INTRUSIONS

i) Penassi Lake Pluton.

ii) North Arm Pluton.

iii) St. Anthony Pluton.

6) LATE- TO POST-TECTONIC QUARTZ MONZONITE INTRUSIONS

i) Goodman Lake Pluton.

ii) Valora Lake-Jigger Lake Pluton.

7) LATE- TO POST-TECTONIC ALKALIC INTRUSIVE COMPLEXES

i) Sturgeon Narrows Alkalic Complex.

ii) Squaw Lake Alkalic Complex.

iii) Bell Lake Alkalic Complex.

Epizonal (Subvolcanic) Intrusions

BEIDELMAN BAY PLUTON

The Beidelman Bay Pluton is an epizonal granitoid sill situated within the lower part of the Darkwater Lake Cycle. It has been mapped previously by Graham (1930), Rodgers (1964), and Trowell (1974a). Horwood (1937a) mapped in detail the Darkwater Lake Mine and a granitoid salient, the Shanty Bay Pluton (Trowell 1970) situated west of Sturgeon Lake, that could be coeval and comagmatic to the Beidelman Bay Pluton. F.M. Vokes (1963) and F.J. Johnston (1968) summarized descriptions of the molybdenum and copper mineralization within this pluton. P. Friske (1974), Franklin (1975, 1977), and Franklin and Gibb *et al.* (1977) have studied the petrography and petrological evolution of the Beidelman Bay Pluton and its associated copper-molybdenum mineralization.

The Beidelman Bay Pluton consists predominantly of trondhjemite, with minor granodiorite, quartz diorite, and quartz-feldspar porphyry.

The trondhjemite is equigranular, fine to medium grained, and has a myrmekitic texture. It consists of plagioclase + quartz + sericite ± biotite ± chlorite ± chloritic biotite ± actinolite + epidote + carbonate. Accessories include opaque oxides, tourmaline, and pyrite. The plagioclase has an "oligoclase" composition, is anhedral to euhedral in form, and is polysynthetically twinned with minor complexly-zoned grains. Quartz occurs as subhedral grains, has irregularly corroded borders, and exhibits undulatory extinction.

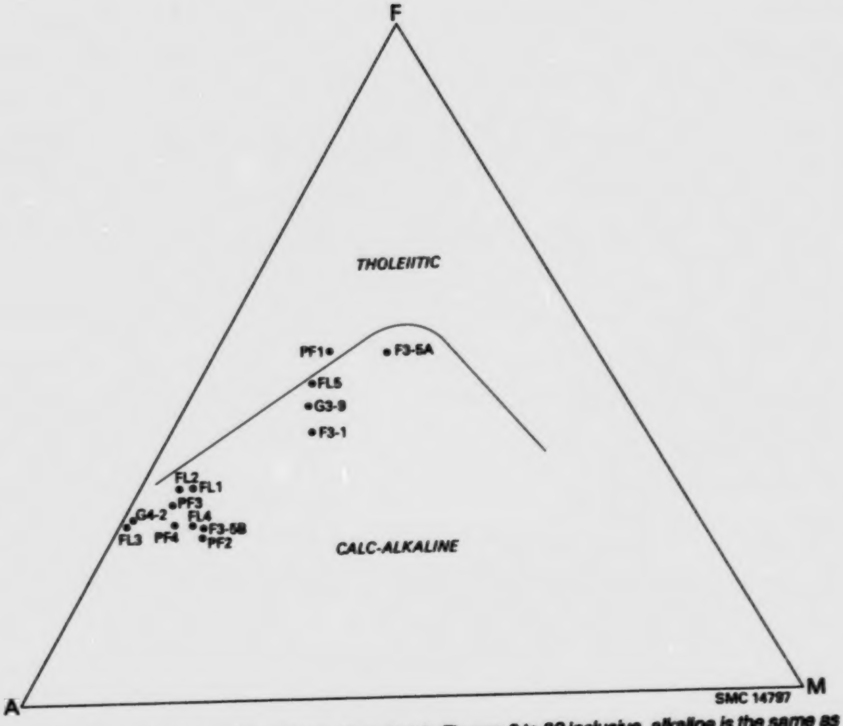

Figure 3–AFM plot, Beidelman Bay Pluton. *Note that in Figures 3 to 32 inclusive, alkaline is the same as alkalic and calc-alkaline is the same as calc-alkalic.*

The granodiorite has a similar texture to trondhjemite, and except for the presence of 3 to 5 percent perthitic microcline, its mineral composition is essentially the same as the trondhjemite.

The quartz diorite is a minor phase confined to the margins (Franklin and Gibb *et al.* 1977); this phase forms predominantly the south margin or base, if this body is a sill. It is characterized by more than 10 percent biotite and hornblende, and anorthite forms cores to the plagioclase grains (Franklin and Gibb *et al.* 1977).

A feldspar to quartz-feldspar phase is irregularly distributed throughout the pluton. It has been interpreted as a late (Trowell 1974a) and as an early (Franklin and Gibb *et al.* 1977) intrusive phase.

Intrusive breccia comprises mafic volcanic xenoliths set in a granitoid matrix and earlier formed granitoid phases set in an aplitic siliceous matrix.

Franklin and Gibb *et al.* (1977) suggest, on the basis of major and minor element data, that the quartz diorite and porphyritic phases were early-formed disequilibrium phases that were subsequently stoped into the later trondhjemite phase.

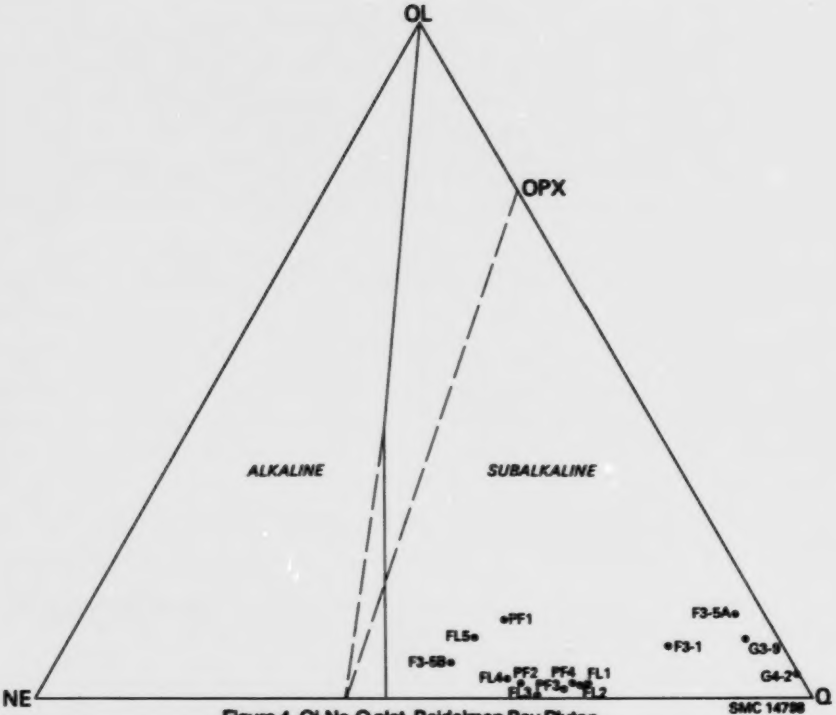

Figure 4—Ol-Ne-Q plot, Beidelman Bay Pluton.

Chemically, this pluton is subalkalic and has a calc-alkalic kindred (Table 3, *on microfiche, back pocket*; Figures 3 and 4).

This pluton is variously massive, foliated, and sheared. Brittle fracturing occurred both as the pluton cooled with the formation of several fracture systems filled by quartz veins and stockworks, and as a result of later faulting.

Evidence for this body being an epizonal intrusion are:

(1) Presence of porphyritic phases;
(2) Possible miarolitic cavities, myrmekitic intergrowths;
(3) Presence of aplitic and absence of pegmatitic dikes;
(4) Abundant fracturing with introduction of quartz veins and formation of quartz stockworks; and intrusive breccia pipes(?) (Trowell 1974a) indicative perhaps of low load pressure.

This pluton is probably a subvolcanic intrusion comagmatic with the overlying felsic metavolcanics. Evidence for this is suggested by the similar chemical compositions of these rock bodies (Franklin and Gibb *et al.* 1977). Absolute age dating of these two units is probably the only definitive method to determine whether both are coeval.

This pluton appears to have been regionally metamorphosed to the greenschist facies rank along with the enclosing metavolcanics. Hydrothermal alteration patterns (Trowell 1974a; Friske 1974; Franklin 1975, 1977; and Franklin and Gibb *et al.* 1977) similar to those developed in porphyry copper systems, however, can still be recognized. Friske (1974) and Franklin (1975, 1977) have compared the alteration and mineralization patterns in this pluton to similar porphyry copper systems emplaced in an island-arc environment (Lowell and Guilbert 1974). The gold mineralization at the Darkwater Mine is associated with a quartz stockwork-alteration zone. The process of gold mineralization may also be due to the same processes that produced the copper and molybdenum mineralization.

The author believes that this pluton may have played a major role in the generation of the massive sulphide deposits in the overlying units (*see* section on "South Sturgeon Lake Assemblage", this report). The copper, and perhaps gold and molybdenum mineralization in this pluton could have been of magmatic derivation or the copper, gold, and molybdenum could have been entrapped by circulating meteoric waters. These elements could have been leached from the fragmental edifice into which this pluton was emplaced.

SHANTY LAKE PLUTON

The author has tentatively assigned the Shanty Lake Pluton (Trowell 1970) to the Epizonal (Subvolcanic) Intrusion grouping. It is similar to the Beidelman Bay Pluton in texture, mineralogy, level of emplacement in the metavolcanics, and in having a zone with molybdenum and copper mineralization. The author did not examine this body during the current study. The discussion below represents a reinterpretation of the original data (Trowell 1970).

This pluton is predominantly granodioritic in composition consisting of plagioclase + microcline and microcline perthite + quartz + biotite ± hornblende. Accessory minerals include sericite, chlorite as an alteration of biotite, magnetite, sphene, and apatite.

Texturally, the granodiorite is medium grained, and has an equigranular to locally myrmekitic texture. Sericitization of the feldspar, chloritic alteration of the biotite, myrmekitic intergrowths, an apparent quartz porphyritic appearance in the immediate area of Shanty Lake, and the nature of the copper and molybdenum mineralization, are all features similar to those seen in the Beidelman Bay Pluton.

This pluton is massive to locally foliated. A granulated appearance, observed in thin section, (Trowell 1970), is suggestive of a similar cataclasis seen in the Beidelman Bay Pluton.

The author also mentioned the presence of a pegmatoid phase, (Trowell 1970), in this pluton. This feature is not usually characteristic of epizonal intrusions. This phase could have formed by a coarsening of grain size accompanying the potassic feldspar alteration.

The copper and molybdenum mineralization comprises; disseminated pyrite, chalcopyrite, and molybdenite in quartz veins, and smears along joint planes in the quartz porphyritic granodiorite.

Batholithic Granitic Complexes

The Sturgeon Lake Volcano-Sedimentary Belt is bounded to the south, east, and northwest by batholithic granitic complexes. Only a small marginal part of each is exposed in the current map-area. Although the three complexes are similar in overall composition and in the presence of several granitoid phases, major differences exist between them with respect to mode of intrusion and contact relations to the volcano-sedimentary belt, and to internal structural style.

WESTERN GRANITIC COMPLEX

From Fourbay Lake to the North Arm of Sturgeon Lake, the contact between the Western Granitic Complex (Trowell 1977) and the volcano-sedimentary belt is interpreted to be mainly fault controlled. Along Highway 599 sheared, crumbly granodiorite is in contact with amphibolitic mafic metavolcanics and metasediments. To the east, foliation in the complex is discordant to that in the volcano-sedimentary belt, and as well, lower metavolcanic flows and interflow metasediments appear to have been removed during the emplacement of the complex. The complex consists of well foliated granodiorite and trondhjemite with subordinate massive to weakly foliated trondhjemite, and subordinate aplite and pegmatite dikes.

Massive to weakly foliated granodiorite-trondhjemite extends along the east shore of the North Arm to the northern border of the map-area (Trowell 1978). Here, large enclaves of metavolcanics appear to have been passively incorporated during emplacement of the granitic phases. Several phases are present, these are characterized by intrusive relationships and by textural differences, and all have essentially the same composition. These phases may in fact be late syntectonic intrusions correlative, perhaps, to the North Arm and the St. Anthony Plutons (*see* unit 7 on Map 2450, back pocket).

EASTERN GRANITIC COMPLEX

Graham (1930), Rodgers (1964), and R.P. Sage *et al.* (1973) describe eastern extensions of this complex. The marginal zone has been previously described (Trowell 1977, 1978).

This complex is predominantly concordant to the volcano-sedimentary belt, but the contact is in part fault controlled east of Vanessa Lake. In the northeast corner of the map-area, a septum of mafic amphibolitic metavolcanics is bounded by two lobes of this complex. The granitic complex consists of several intrusive phases. Early phases are metamorphosed, well foliated to gneissic, biotite and hornblende-biotite granodiorite and trondhjemite. Microcline phenocrysts and quartz lenticules are composed of lensoid sutured quartz aggregates that developed during cataclasis and occur locally. These early granitic phases occur as enclaves in younger granitic phases are locally fault bounded, and commonly show tight internal folding.

Massive to weakly foliated equigranular to locally porphyritic (microcline) trondhjemite, granodiorite, and locally quartz monzonite and subordinate aplite and pegmatite comprise the younger granitic phases. To the north and east, there is a gradation from trondhjemite-granodiorite to granodiorite-quartz monzonite (Trowell 1978).

SOUTHERN GRANITIC COMPLEX

The Southern Granitic Complex (Trowell 1974a and b) comprises two zones: (1) a northern zone of amphibolitic mafic metavolcanics extensively intruded by granodiorite-trondhjemite forming layered and agmatite arrays, and (2) a southern zone of strongly foliated to banded or gneissic structured trondhjemite-granodiorite with locally sparse amphibolite xenoliths.

The northern zone is extensively developed in the Bell Lake area where concordant sheets of granitic material have been emplaced in the basal mafic metavolcanic sequence of the South Sturgeon Lake Assemblage. It thins appreciably, and effectively pinches out both to the east and west.

Granitic phases are dominantly biotite and hornblende-biotite granodiorite-trondhjemite with subordinate amounts of biotite-hornblende and porphyritic granodiorite-trondhjemite and minor quartz monzonite and massive trondhjemite. Aplite, pegmatite, and feldspathic and quartz-feldspar mobilizates intrude the granitoid and amphibolite phases. Folding of the granitic phases has taken place and *lit-par-lit* arrays are present. Table 3a presents three analyses from the Southern Granitic Complex.

Syenite-Monzonite-Granodiorite Plutons

Monzonite-granodiorite plutons intrude the Sturgeon Lake Volcano-Sedimentary Belt along its eastern margin and continue to the east outside the map-area (Rodgers 1964). Although individual plutons are present, the plutons taken together crudely define a crescent-shaped zone. W.M. Schwerdtner (1976), R.H. Sutcliffe (1977), and Schwerdtner, and Sutcliffe (1978) have described similarly-shaped intrusions. These authors, have proposed a model for emplacement of these crescent-shaped bodies that uses strain studies of the internal fabric of these bodies . These bodies are late sheet-like intrusions emplaced along prominent lithological interfaces, possibly in conjunction with synformal downwarping.

Similarities between the crescent-shaped zone of the map-area and those areas described by Schwertner (1976), Sutcliffe (1977), and Schwerdtner and Sutcliffe (1978) include these features; similar mineralogical compositions and textures, the presence of mafic amphibolitic clots, emplacement along an apparent synformal structure, and intrusion by later quartz monzonite pluton(s). In contrast to the intrusions described by the above authors, plutons in the map-area:

(1) Intrude into the volcano-sedimentary belt, but are close to the con-

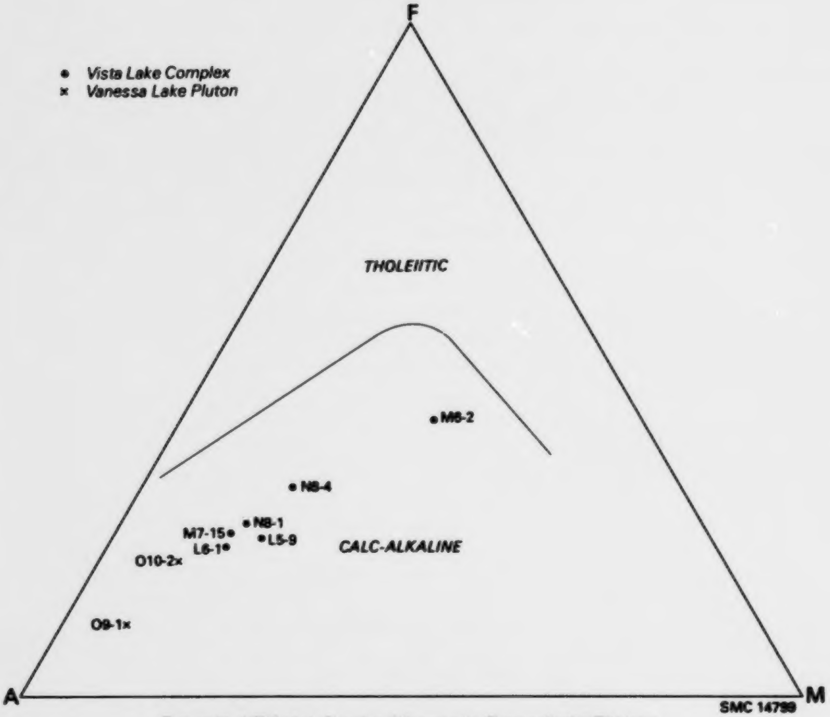

Figure 5–AFM plot, Syenite-Monzonite-Granodiorite Plutons.

tact with the Eastern Batholith Complex, rather than at the interface between these two terranes;

(2) The Vista Lake Complex, for example, contains enclaves of metasedimentary rock in addition to mafic amphibolitic enclaves and clots;

(3) While the author did not investigate these plutons thoroughly to determine if their structural style is similar to that described for intrusions studied by the above authors. The presence in the Vanessa Lake Pluton, of a locally developed cataclastic foliation indicates some differences in structural style;

(4) These plutons, especially the Vista Lake Complex, are composed of more than one intrusive phase, whereas the intrusions described by the above authors were generally emplaced as one phase.

The author suggests, however, that the mode of emplacement and derivation of these plutons represent only minor modifications of the structural and genetic models proposed by the above authors.

R.H. Sutcliffe (1978) is trying to determine if the Jackfish-Weller Lake Pluton was derived by partial melting of a mafic crustal source. The author (Tro-

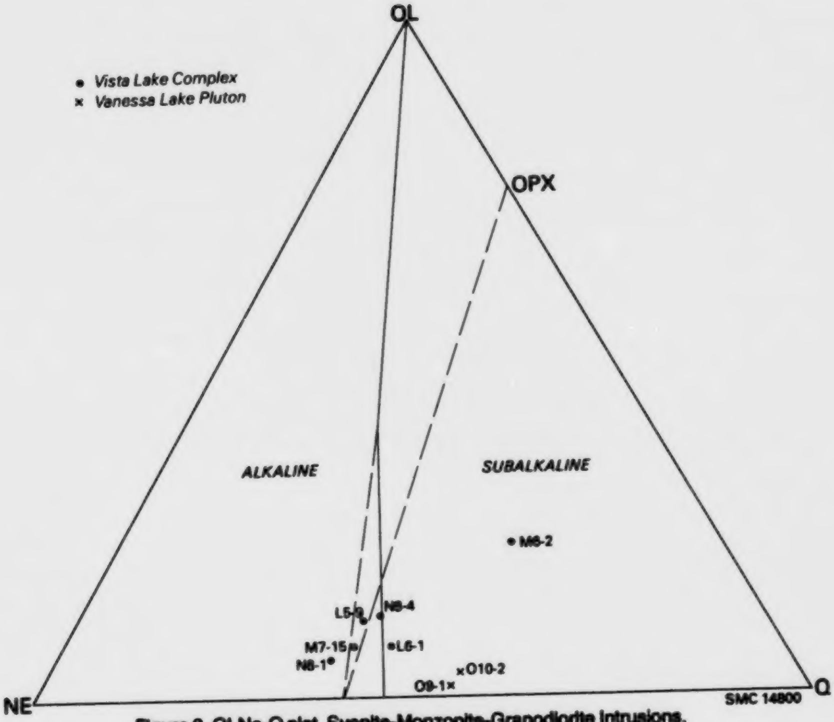

Figure 6–Ol-Ne-Q plot, Syenite-Monzonite-Granodiorite Intrusions.

well 1977) after personal communications with W.M. Schwerdtner, G.R. Edwards, and R.H. Sutcliffe, proposed that the crescent-shaped zone in the map-area was formed by partial melting of metasediments and mafic metavolcanics.

The chemistry of samples collected from the Vista Lake Complex and Vanessa Lake Pluton are presented in Tables 4 and 5, and the results graphically shown in Figures 5 and 6. The data is limited and mainly shows the predominant subalkalic character of these rocks. There is, however, a relatively wide scatter of data for the Vista Lake Complex which is suggestive of a more complex magmatic evolution. This evolution is perhaps similar to that outlined below.

VISTA LAKE COMPLEX

The Vista Lake Complex is a crescent-shaped multiphase intrusion that intrudes metasediments of the Sturgeon Lake Volcano-Sedimentary Belt and the bordering granitoid rocks. The metasediments are bounded by mafic metavolcanics to the west. Narrow slices of metasediments and mafic metavolcanics occur intermittently along the eastern contact of the Vista Lake Complex. These rocks may represent the remnant of a once continuous rind of metavolcanics and metasediments that defined the eastern boundary of the volcano-sedimentary belt adjacent to the Vista Lake Complex. If the structure is synclinal, mafic metavolcanics could underlie the metasediments at a lower crustal level than is presently exposed. Chemically, this complex is composed of both alkalic and subalkalic phases (Table 4, Figures 5 and 6). Granodiorite and monzonite predominate, but syenodiorite and quartz syenite phases are also present. Mafic mineral and quartz contents vary widely. The texture varies from medium-grained equigranular, to coarse-grained inequigranular, to feldspar porphyritic.

The mineral assemblage comprises quartz + plagioclase (oligoclase) + alkali feldspar (microcline, microcline perthite ± antiperthite) + hornblende ± biotite ± chlorite ± pyroxene ± iron-titanium oxides + sphene. Accessory minerals include pyrite, apatite, carbonate, epidote, hematite, zircon, allanite, and fluorite. Antiperthite due to potassic metasomatism is variably developed throughout the body.

Inclusions consist of large septa of metasediments stoped in during emplacement of the intrusion, as well as cognate mafic clots and patches. The mafic clots and patches are generally composed of hornblende mantled by biotite, but Rodgers (1964, p.32) did report remnant pyroxene. The author originally interpreted these clots and patches as mafic metavolcanic inclusions. It is possible that the Vista Lake Complex was anatectically derived by partial melting of volcanic rocks and sedimentary rocks. In this case, the mafic masses could represent the mafic residuum of the mafic volcanic rocks from which an anatectic melt (plagioclase rich, minor quartz, rare to no potassic feldspar) was derived. Interaction between the anatectic melt from the volcanic rocks with potassic fluids produced by partial anatexis or just heating of water in the pore spaces of the sedimentary rocks might explain the potassic metasomatism, and the emplacement of later potassic plutons (*see* the Goodman Lake Pluton, for example).

FLINDT RIVER PLUTON

The Flindt River Pluton (Trowell 1977) has an irregular, roughly lensoid shape. Rather than being a single body (pluton), this pluton may comprise a series of dikes or apophyses from the Vista Lake Complex. It has intruded into, and contains xenoliths of metasediments and mafic metavolcanics of almandine-amphibolite facies rank.

It is predominantly composed of granodiorite which grades locally to quartz monzonite and monzonite. Its mineral composition consists of plagioclase and antiperthite, microcline, quartz, hornblende, biotite, and chlorite. Accessories include iron-titanium oxides, pyrite, epidote, carbonate, apatite, and sphene. Texturally, it is a medium-grained, equigranular to porphyritic rock.

Quartz monzonite veinlets and dikelets cut both the pluton and its host rocks.

VANESSA LAKE PLUTON

The Vanessa Lake Pluton (Trowell 1977) is a lensoid-shaped body, 8 km long by 0.6 km wide. It intrudes concordantly almandine-amphibolite facies rank mafic metavolcanics and metasediments.

This pluton varies in composition from granodiorite to quartz monzonite, and locally to monzonite. It is of calc-alkalic affinity (Table 5, Figures 5 and 6). The mineral composition comprises plagioclase (oligoclase) and antiperthite + microcline and microcline antiperthite + quartz + hornblende ± chlorite. Accessories include: magnetite, pyrite, hematite, sphene, zircon, epidote, and apatite. Texturally, it is a medium- to coarse-grained, equigranular to porphyritic rock which is foliated to sheared.

Antiperthite formed by replacement of primary plagioclase by secondary potassic feldspar, is variably developed. Plagioclase grains can be both unaltered and can be almost completely replaced by microcline.

The chilled marginal phases of this pluton consist of leucocratic trondhjemite. Agmatite breccia is not common, and consists of mafic metavolcanic xenoliths set in a trondhjemite matrix. Minor granodiorite sills and dikes occur as offshoots of this pluton.

BECKINGTON LAKE EAST PLUTON

A small pluton or group of sills underlie and outcrop on the shore of the lake situated east of the south end of Beckington Lake. This pluton intrudes upper greenschist facies rank mafic metavolcanics.

This body varies in composition from biotite-hornblende granodiorite to monzonite. Texturally, it is a medium-grained equigranular to locally porphyritic rock.

Sills having a similar composition and texture, intrude mafic metavolcanics situated between the above-mentioned lake and Vanessa Lake.

This body defines the northern extent of the crescent-shaped syenite-monzonite-granodiorite intrusion zone.

Intrabelt Late-Tectonic Granodiorite Intrusions

Three plutons, predominantly composed of granodiorite, intrude the Sturgeon Lake Volcano-Sedimentary Belt. These plutons are the Mountain Island Bay and Granite Bay Plutons (Trowell 1974), and the Saunders Lake Pluton (Trowell 1976).

Previously reported granitic rocks situated east of Byline Lake (Trowell 1974a) were subsequently reinterpreted to be a dike comagmatic with the felsic to intermediate metavolcanics of this area (Trowell 1976a). It is possible, however, that this dike could be an apophysis of the Saunders Lake Pluton. Only a small part of the Saunders Lake Pluton was actually covered by mapping. The intrabelt position of this pluton is the sole criterion for placing it in this group-

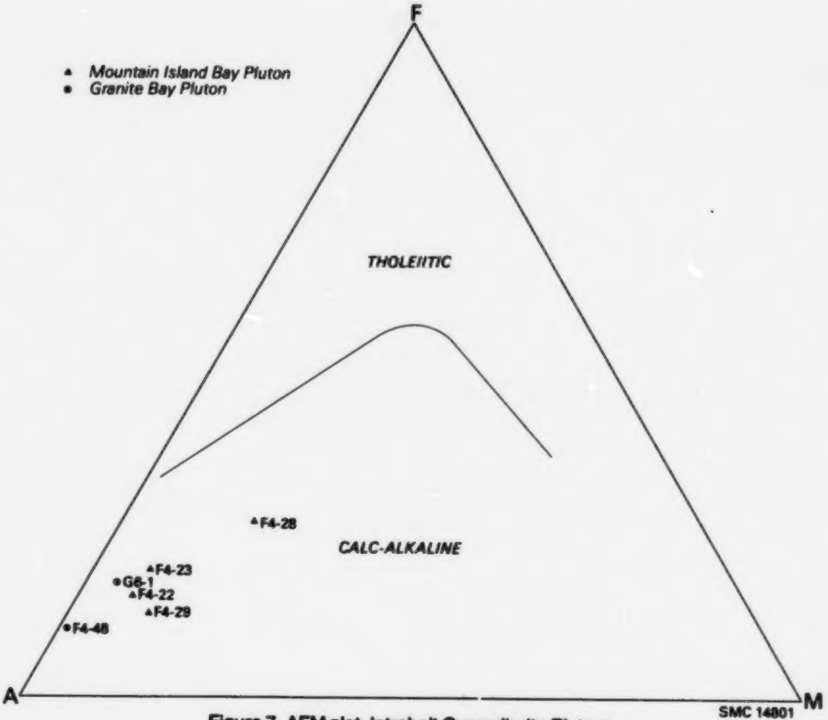

Figure 7–AFM plot, Intrabelt Granodiorite Plutons.

ing of felsic to intermediate intrusive rocks.

The Mountain Island Bay and Granite Bay Plutons intrude mafic metavolcanics of the Central Sturgeon Lake Assemblage. Intrusion was post-folding as indicated by deflections produced by these plutons of the fold axial traces within the mafic metavolcanics. The plutons are not foliated but are locally sheared. Contact metamorphism of the hornblende hornfels and albite-epidote facies accompanied intrusion of these plutons. Superposition of contact metamorphism on the regional greenschist metamorphism supports the conjecture that these are late plutons.

The chemistry of samples collected from these two plutons is presented in Tables 6 and 7, and Figures 7 and 8. These rocks are subalkalic and of calc-alkalic affinity.

These two intrusions could be joined at depth with, and thus coeval and comagmatic to, phases of the large granitic mass situated west of Sturgeon Lake (Horwood 1937a). Intrusion likely occurred during the waning stages of orogenesis accompanying final readjustments between the volcano-sedimentary belt and the enclosing granitic rocks.

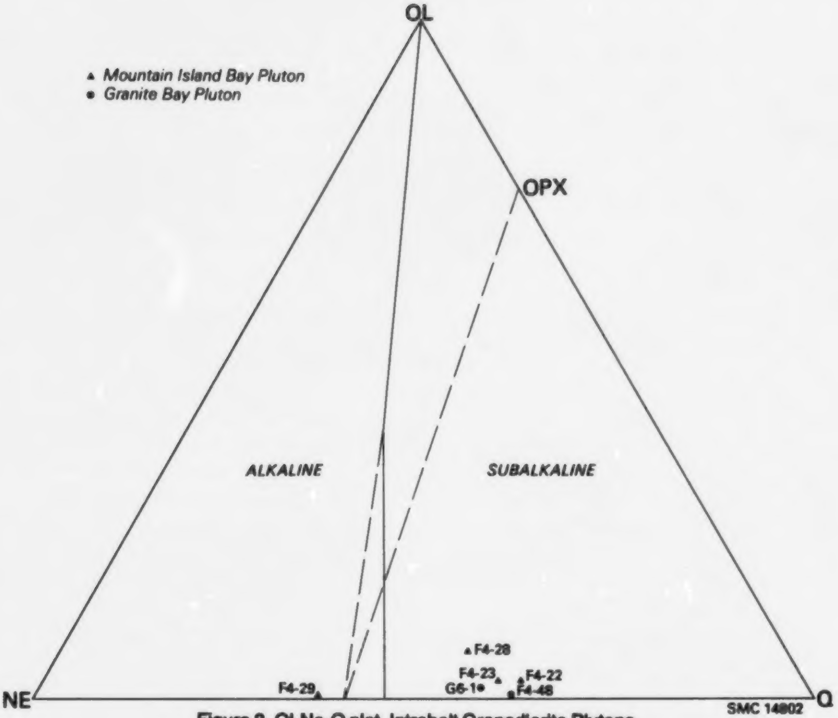

Figure 8–Ol-Ne-Q plot, Intrabelt Granodiorite Plutons.

MOUNTAIN ISLAND BAY PLUTON

The Mountain Island Bay Pluton (Trowell 1974) was intruded along the axial trace of an anticline in folded mafic metavolcanics. Contact relationships vary from concordant to discordant. Local agmatite breccia zones consist of mafic metavolcanic xenoliths set in a "hybrid" hornblende syenite matrix.

These rocks are granodiorite and vary in composition to trondhjemite and quartz monzonite. The rocks vary in texture from fine to coarse grained, and from equigranular to locally porphyritic. The mineral composition is: plagioclase (albite-oligoclase) + microcline and microcline perthite ± quartz ± hornblende/actinolite ± biotite ± chlorite ± carbonate. Accessories include sphene, iron-titanium oxide, hematite, leucoxene, and locally myrmekite.

Dikes of aplite, granodiorite, syenite, diorite, and irregular masses of pegmatite cut the host rocks.

The southern boundary of this pluton is bounded by a fault.

GRANITE BAY PLUTON

The Granite Bay Pluton is comagmatic and coeval to the Mountain Island Bay Pluton, and is almost identical to it in composition and style of intrusion. Its areal extent (Trowell 1974a) was reinterpreted and subsequently enlarged from interpretation of detailed ground magnetic and gravimetric surveys (Barlow 1974a, 1974b, 1975b).

SAUNDERS LAKE PLUTON

A part of a felsic intrusion of unknown extent was mapped on the shore and west of Saunders Lake. A composition approximating granodiorite was inferred from field observations. Texturally, the rocks are equigranular and vary from medium to coarse grained.

The mineral assemblage of one sample from the previously interpreted granitoid salient east of Byline Lake is plagioclase (albite- oligoclase) + microcline + quartz + biotite + hornblende with minor epidote and apatite (Trowell 1974a). The mineralogy corresponds to a granodiorite composition for this body and lends some credence to this body having a granitic affinity. The body is possibly an apophysis of the Saunders Lake Pluton. The author's original observation (Trowell 1974a) that this body is of granitic affinity is perhaps correct. The observation (Trowell 1976a) that it is of subvolcanic affinity is probably incorrect.

Extra-Belt Trondhjemite-Granodiorite Plutons

Three trondhjemite-granodiorite plutons were mapped along the margins of the Sturgeon Lake Volcano-Sedimentary Belt. These plutons intrude mafic metavolcanics, and in the case of the North Arm and St. Anthony Plutons, the Western Granitic Complex. The exact boundaries of these plutons have not been precisely determined. The Penassi Lake Pluton is slightly more potassic than either the North Arm or St Anthony Plutons. It also is foliated in contrast to their generally massive appearance.

In addition to the North Arm and St. Anthony Plutons, massive trondhjemite-granodiorite is found intermittently along the eastern and northern shores of the North Arm of Sturgeon Lake. Several textural varieties including equigranular rocks and plagioclase, quartz, and plagioclase-quartz porphyritic rocks were recognized intruding one another as sills, dikes, and irregular masses. These rocks have a similar composition of biotite ± hornblende trondhjemite-granodiorite. It is possible that a large irregularly shaped body of trondhjemite-granodiorite underlies the North Arm of Sturgeon Lake. The North Arm and St. Anthony Plutons could be lobes of this body.

The criterion for this grouping is simply one of position. While the North Arm and St. Anthony Plutons are likely comagmatic and coeval, (*see* section on

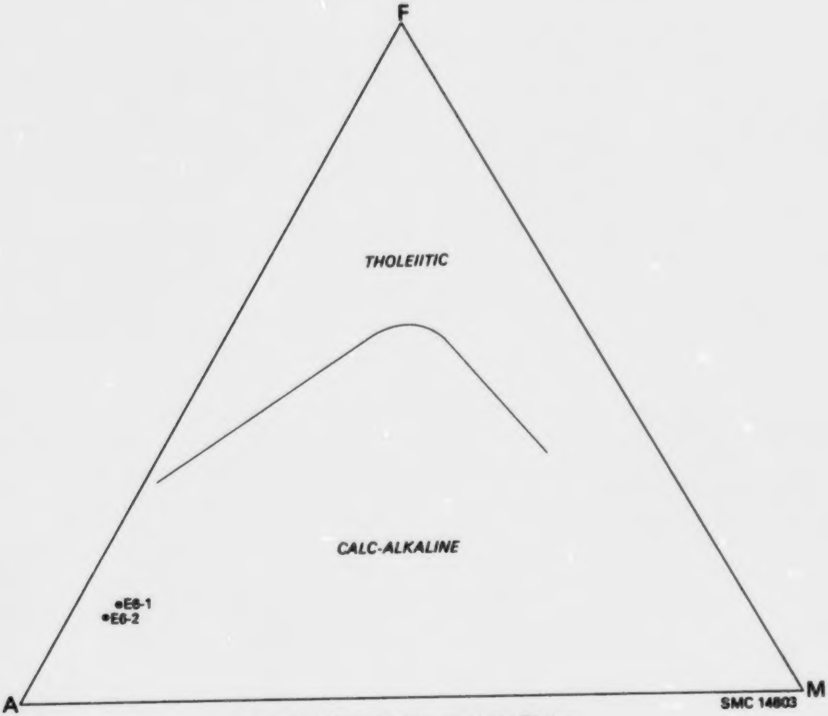

Figure 9–AFM plot, Penassi Lake Pluton.

"Age Relations of Felsic and Intermediate Intrusive Rocks") the Penassi Lake Pluton may be more closely related to the Intrabelt Granodiorite-Trondhjemite Plutons. It does intrude the same mafic metavolcanic units as do the Mountain Island Bay and Granite Bay Plutons. Its composition is also similar to the Mountain Island Bay and Granite Bay Plutons.

PENASSI LAKE PLUTON

A part of a granitic pluton has intruded mafic metavolcanics in the vicinity of Penassi Lake. The pluton comprises granodiorite-quartz monzonite with subordinate trondhjemite. Minerals present include; quartz + albite-oligoclase + microcline + biotite + hornblende ± epidote ± sericite ± sphene. Accessories include iron-titanium oxide, leucoxene, apatite, and hematite. Dikes and irregular masses of aplite and pegmatite occur.

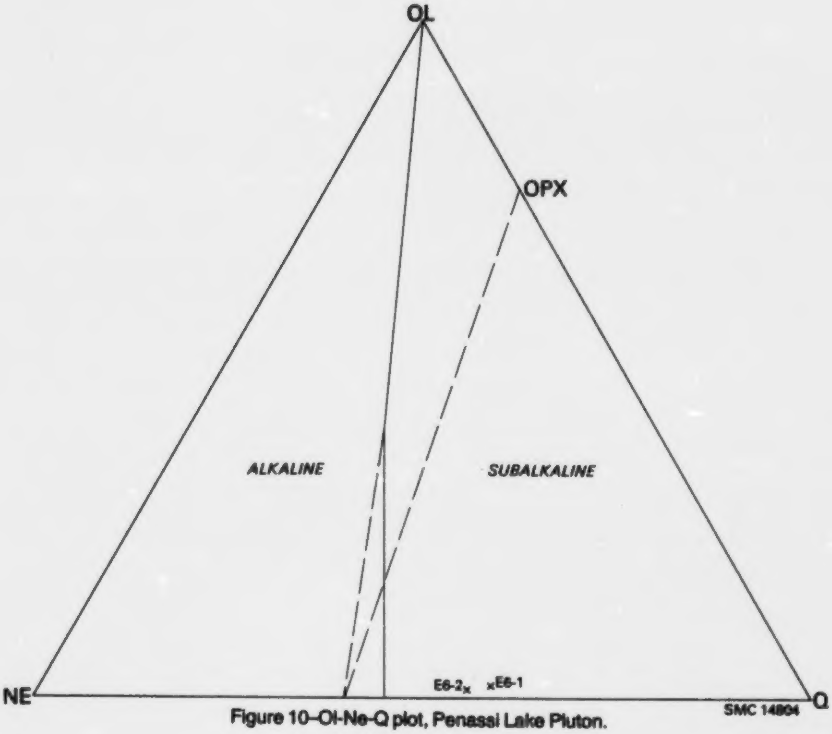

Figure 10–Ol-Ne-Q plot, Penassi Lake Pluton.

The pluton appears to have forcibly intruded the metavolcanic sequence deflecting the foliation trend from east to north. Faulting east of Penassi Lake may also be a result of its intrusion. In contrast to the other marginal plutons the Penassi Lake Pluton is generally foliated. Table 8 and Figures 9 and 10 indicate its subalkalic character and calc-alkalic affinity respectively. The pluton perhaps is compositionally more closely related to the intrabelt granodiorite-trondhjemites (*see* Figures 7 and 8).

NORTH ARM PLUTON

The North Arm Pluton (Trowell 1977; Graham 1930) is an irregularly shaped mass that intrudes mafic metavolcanics and the Western Batholithic Complex. Relatively unaltered fragments of both these host rocks occur within this body. This body consists of massive, to locally sheared, trondhjemite-granodiorite. Quartz-plagioclase porphyritic phases are present. Associated porphyritic dikes of a similar composition intrude mafic metavolcanics in King Bay and along the Northeast Arm of Sturgeon Lake. The mineral assemblage of this body and its associated dikes is: plagioclase (oligoclase) + quartz ± microcline + biotite ± hornblende ± chlorite. Accessories include epidote, magnetite, sphene, apatite, and zircon.

This pluton may be a part of a much larger mass that underlies the North Arm of Sturgeon Lake.

ST. ANTHONY PLUTON

The St. Anthony Pluton (Trowell 1977; Graham 1930; Gledhill 1924) is a subcircular stock that intrudes mafic metavolcanics on and west of Couture Lake. This pluton may be a lobe of a much larger mass within the North Arm of Sturgeon Lake. If so, the pluton is probably coeval and comagmatic with the North Arm Pluton. The St. Anthony Pluton is also likely to be intrusive into the Western Granitic Complex.

The rocks of this pluton weather pink, white, and brown, and are generally pink to grey on the fresh surface. These rocks are medium grained, equigranular to slightly porphyritic, containing plagioclase phenocrysts, and are massive to locally weakly foliated. A quartz porphyritic phase, locally highly sheared to a quartz-sericite schist, occurs along the contact with the mafic metavolcanics in the immediate area of the former St. Anthony Mine. Gold-bearing quartz veins, locally approaching a quartz stockwork, occur within the pluton and the adjoining mafic metavolcanics.

The mineral assemblage of this pluton is: sodic plagioclase + quartz + microcline ± biotite ± muscovite and approximates a granodiorite to locally quartz monzonite composition. Accessories include pyrite, epidote, carbonate, apatite, and opaque oxides. Additional accessory minerals identified in the ore zone of the former St. Anthony Mine include the gangue minerals: quartz, calcite, and siderite, and the sulphide minerals, pyrite, chalcopyrite, galena, sphalerite, and marcasite.

The muscovite occurs as discrete grains and as an alteration product of the biotite. Muscovite was probably formed by a process of hydrothermal alteration during generation of the ore zone. The author has previously speculated (Trowell 1977) that the mineralization was a result of hydrothermal "upgrading" by the St. Anthony Pluton of an original gold-bearing carbonate stratiform horizon in the mafic metavolcanics.

Late- to Post-Tectonic Quartz Monzonite Intrusions

VALORA LAKE - JIGGER LAKE PLUTON

The Valora Lake - Jigger Lake Pluton (Trowell 1974a) is a semi-circular to elliptical stock that intrudes mafic metavolcanics and rocks of the Southern Batholithic Complex. It consists predominantly of quartz monzonite with subordinate granodiorite.

The rocks are commonly pink on fresh surfaces and pink, white, pale orange, or pale yellow on weathered surfaces. These rocks are generally medium grained, though fine- to coarse-grained zones are present. Textures are equigranular to locally porphyritic. Alteration of the feldspars has produced a crumbly weathered surface.

Their mineral assemblage comprises: plagioclase (oligoclase) + microcline perthite + quartz + biotite ± hornblende ± chlorite (alteration of biotite) + epidote. Accessories include iron-titanium oxide and sphene. The presence of myrmekite and the local coarse-grained porphyritic texture is perhaps indicative of a moderate to high level of emplacement.

This stock is massive to weakly foliated near the margin, and well jointed. Contacts, except for rare intrusion breccia, are sharp with little evidence of contamination. Dikes of a similar composition cut the mafic metavolcanics marginal to the stock.

GOODMAN LAKE PLUTON

A quartz monzonite stock underlies Goodman and King Lakes. It is medium-grained, generally equigranular to locally microcline porphyritic, and light grey to light pink and massive. Except for uncommon granodiorite-trondhjemite dikes, the homogeneous texture, mineralogy, and chemistry of this body (Table 9, Figures 11 and 12) indicate that it consists predominantly of one phase.

The mineral assemblage comprises: quartz + plagioclase (albite-oligoclase) + microcline + biotite ± chlorite ± hornblende + muscovite + sphene + opaque minerals. It is distinct chemically (Table 4, Figure 5 and 6) from the Vista Lake Complex that it apparently intrudes. All samples analyzed, with the exception of Sample M7-1 (Table 9), are slightly corundum normative.

Alkalic Intrusive Complexes

Three alkalic intrusive complexes are present in the map-area. These complexes are (1) the Sturgeon Narrows Complex, (2) the Squaw Lake Complex, and (3) the Bell Lake Complex. These complexes have been described previously (Trowell 1974a, 1977). Additional mapping and chemical sampling of the Sturgeon Narrows and Squaw Lake Complexes (Trowell *et al.* 1979; Sage 1982 in preparation) have led to modifications to the original description and interpretation of them. Chemical analyses were performed on previously collected samples of the Bell Lake Complex, and led to the reinterpretation of this complex as having an alkalic rather than a calc-alkalic (Trowell 1974a) parentage.

The Sturgeon Narrows and Squaw Lake Complexes both contain modal feldspathoidal minerals, but the Bell Lake Complex is nepheline normative. On an alkali-silica diagram (*see* Figure 13), the Sturgeon Narrows and Squaw Lake Complexes plot in the "alkalic basalt" and "miaskitic (alkalic) syenite"

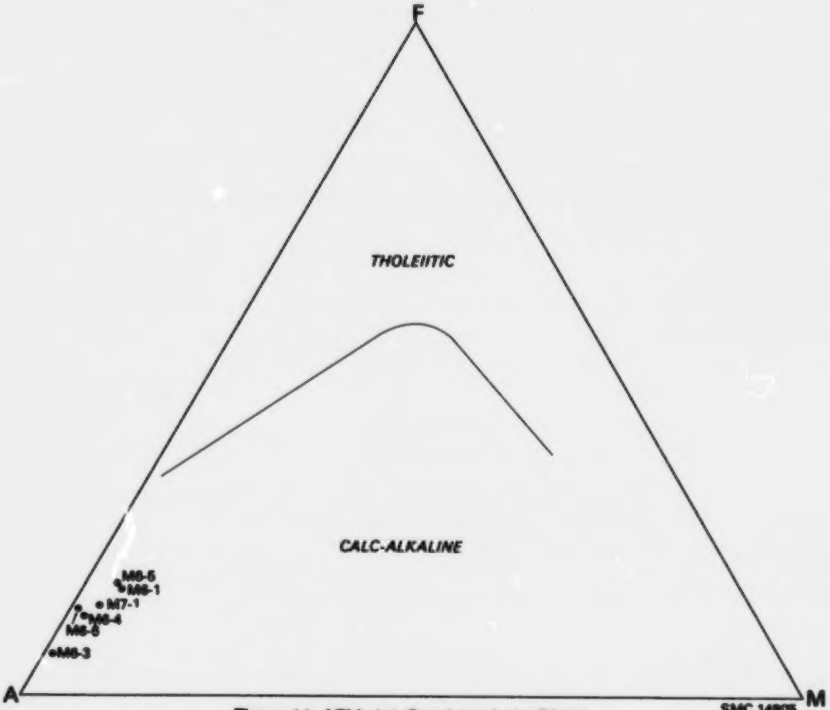

Figure 11–AFM plot, Goodman Lake Pluton.

fields (Currie 1976). The few samples that plot in the "agpaitic (peralkalic) syenite" (Currie 1976) field likely represent altered miaskitic syenite rocks.

The Bell Lake Complex plots in the "alkalic basalt" field. The two samples with low alkali and silica values are from the pyroxenitic phase of this complex. The separation between the plotted positions of these samples and that of the major syenitic part of this body supports the interpretation that the pyroxenitic phase formed as an initial cumulate ultramafic member (Hoad 1970).

The Sturgeon Narrows and Squaw Lake Complexes are comagmatic and coeval intrusions. These intrusions were initially emplaced into relatively high crustal levels as indicated by the presence of: miarolitic cavities; coarse-grained, almost pegmatoid texture; and narrow to nonexistent fenite zones (Heinrich 1966). Both complexes show a zoned structure marked by a gradation from salic in the interior to more mafic phases at the margin. It is feasible, because of their high crustal level of emplacement, that these complexes had associated volcanic rocks of similar composition. None, however, have been recognized. Both complexes show definite intrusive relations to their host rocks.

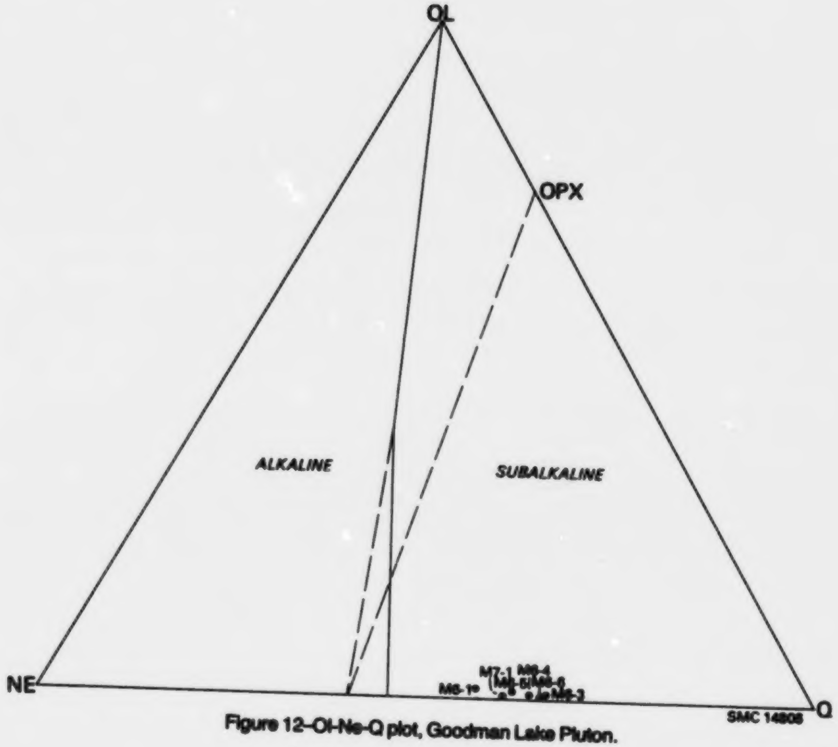

Figure 12–Ol-Ne-Q plot, Goodman Lake Pluton.

The Sturgeon Narrows Complex has, however, been cataclastically deformed by movement along the Sturgeon Narrows Cataclastic Zone. As well, the alteration of the original mafic minerals within this complex to chlorite, actinolite, and biotite + garnet + epidote ± actinolite aggregates, reflects late metamorphism of this body. For these reasons, the author interprets these complexes to have been emplaced prior to the cessation of orogenic activity. Thus, they are probably of Archean age.

The Bell Lake Complex is an alkalic basalt complex that shows relatively strong differentiation from cumulate ultramafic to the development of minor salic residuals. In contrast to the Sturgeon Narrows and Squaw Lake Complexes, this complex was emplaced marginal to the volcano-sedimentary belt. The Bell Lake Complex is probably coeval and comagmatic to the other two complexes.

These three intrusions, taken together, represent a unique alkalic province apparently unrelated to any major belts of alkalic rocks (Barker 1974; Currie 1976) or to any major structural features.

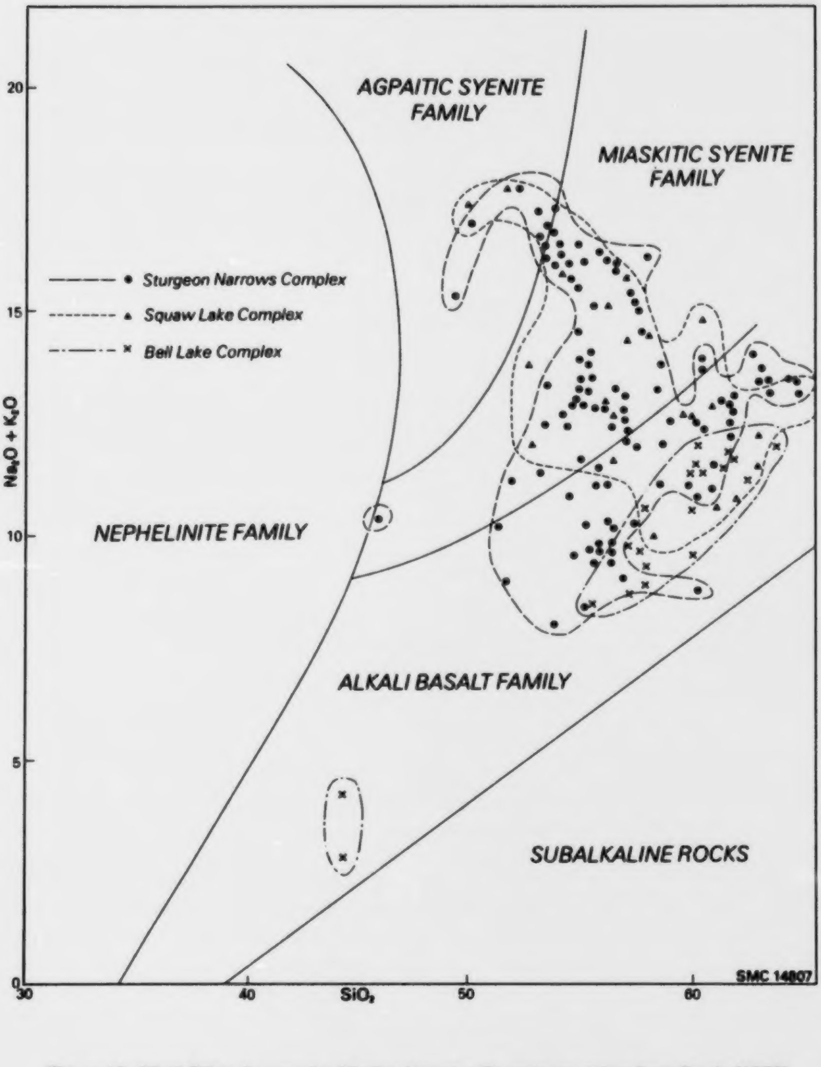

Figure 13–Alkali-Silica diagram for Alkaline Intrusive Complexes, taken from Currie (1976).

The Sturgeon Narrows Alkalic Complex is a zoned, tadpole-shaped stock, about 13.7 km long, and is elongated in a northeasterly direction. It intruded and slightly fenitized deformed Early Precambrian, greenschist facies rank, mafic metavolcanics and metasediments. Emplacement of the Sturgeon Narrows Alkalic Complex is probably related to faulting as is indicated by its spatial association to the Sturgeon Narrows Cataclastic Zone. Protoclastic deformation is the result of late intrusive movement within the complex itself, while shear and breccia zones resulted from post-emplacement movement along the Sturgeon Narrows Cataclastic Zone.

The composition of the complex varies from syenodiorite at its margin to feldspathic leuco-syenite at its core. Three compositional zones were mapped (Trowell 1977; Trowell *et al.* 1979; Sage 1982 in preparation). These zones are from the margin (situated to the northeast) to the core:

(1) Syenodiorite,
(2) Outer Syenites,
(3) Inner Feldspathic Leucosyenite.

Syenodiorite is best exposed along the northeast margin of this complex. The rock is generally massive to weakly foliated, fine to medium grained, locally coarse grained, and varies from being equigranular to porphyritic. The rock weathers various shades of brown, pink, grey, and green. On fresh surfaces it is pink to brown. The rock is characterized by an excess of 25 percent mafic minerals, and consists of varying amounts of plagioclase (An_0-An_{20}), microcline and microcline perthite, orthoclase (cryptoperthite), antiperthite, augite, amphibole, biotite, primary garnet, nepheline, and magnetite. Quartz locally composes up to 5 percent of the rock. Accessories include apatite, actinolite, sphene, fluorite, tourmaline, and chlorite.

The Outer Syenites are coarse- to medium-grained rocks, and vary in texture from being equigranular to porphyritic. The grain size of the rock shows a general decrease in size from the margins inward. These rocks weather various shades of grey, blue, white, and pink. On fresh surfaces the rocks are similarly coloured, but have darker hues. Mafic mineral content varies from 10 to 25 percent. The marginal units show a well-developed trachytoidal texture, and consist of varying amounts of plagioclase (An_0-An_{20}), microcline and microcline perthite, orthoclase (cryptoperthite), antiperthite, aegirine-augite and augite, amphibole (sodic), biotite, nepheline, garnet, cancrinite, sodalite, zeolites (primarily natrolite and analcite), sericite (gieseckite), scapolite, sphene, and fluorite. Accessories include zircon(?), apatite, calcite, chlorite, magnetite, and pyrite. Augite is characteristic of the marginal units with aegirine-augite occurring towards the interior. Nepheline is commonly altered to zeolites and sodalite. X-Ray identification (Geoscience Laboratories, Ontario Geological Survey, Toronto) indicates cancrinite is occasionally present; in which case, it could also be an alteration of nepheline as well as forming primary grains.

The Inner Feldspathic Leucosyenite is massive, fine to medium grained, and equigranular, but pegmatite segregations occur locally. Weathered and fresh surfaces are white, buff, and pale pink. Mafic mineral content averages 10 to 15 percent. The rock consists of varying amounts of plagioclase (An_0-An_{20}), microcline and microcline perthite, orthoclase (cryptoperthite), aegirine-augite, biotite, nepheline, garnet, and zeolites. Accessories include; fluorite, zircon(?), sphene, magnetite, scapolite, calcite, and apatite.

Lamprophyre, and medium- to fine-grained equigranular, pegmatitic, and aplitic syenite dikes occur sporadically throughout this complex.

SQUAW LAKE ALKALIC COMPLEX

The Squaw Lake Alkalic Complex is an oval to sub-elliptical stock about 4.4 km long, and is elongated in a northern direction. The complex is similar to the Sturgeon Narrows Complex, in that it has intruded and slightly fenitized deformed Early Precambrian greenschist facies rank mafic and felsic metavolcanics. The complex was probably emplaced by a mechanism similar to that for the Sturgeon Narrows Complex, but no surface manifestations of an underlying structural control are apparent.

Two compositional groupings are recognized by the author. These groupings are:

(1) Syenite and nepheline syenite that comprise the majority of this complex,

(2) Monzonite, and syenomonzonite, that occur along the north and west margins of the complex.

The syenite and nepheline syenite are medium- to coarse-grained, and inequigranular porphyritic rocks. These rocks weather white to grey to pink to red with various hues of orange, green, and yellow. Fresh surfaces are white to pink. Marginal phases exhibit a trachytoidal texture. These phases consist of varying amounts of microcline perthite and microcline, orthoclase, plagioclase, (An_{12-14}), sericite (gieseckite), nepheline, aegirine-augite, biotite, amphibole, orthopyroxene, cancrinite, zeolites (stilbite, analcite, natrolite), magnetite, and calcite. Quartz occurs in syenite in amounts up to 5 percent. Accessories include pyrite, sphene, apatite, garnet, olivine and iddingsite, and scapolite.

The monzonite, and syeno-monzonite, are fine- to medium-grained, equigranular to porphyritic and massive rocks. These rocks are composed of varying amounts of plagioclase (An_{12}), microcline and microcline perthite, and antiperthite, quartz, sericite, biotite, and alkali amphibole pseudomorphic after clinopyroxene. Accessories include calcite, chlorite, pyrite, magnetite, sphene, and garnet.

Pegmatitic nepheline syenite dikes occur locally and cut the other phases of this complex.

The syenite and monzonite phases appear to the have been emplaced prior to intrusion of the alkalic phases. This observation is opposite to what might be expected during the differentiation of a miaskitic syenite complex. In such a complex, the saturated, quartz-bearing phases would be expected to occur as late phases of such complexes.

BELL LAKE ALKALIC COMPLEX

An elliptical stock, the Bell Lake Alkalic Complex, underlies the northern part of Bell Lake (Rodgers 1964; Hoad 1970; Trowell 1974a). It intrudes the agmatite zone of the Southern Granitic Complex. Additional chemical data indicates that it has an alkalic kindred (see below) rather than calc-alkalic as previously suggested (Trowell 1974a). Contacts between the stock and the Southern Granitic Complex are variously chilled, faulted, and gradational. The complex can be subdivided into three broad groupings:

(1) Ultramafic and mafic rocks,
(2) Mesotype monzonite,
(3) Leucocratic monzonite.

Pegmatite, aplite, and lamprophyre dikes intrude the stock. Mafic and ultramafic inclusions occur throughout the mesotype monzonite. Intrusion breccia containing apparent volcanic and granitoid inclusions locally occurs along the margin of the stock. This breccia probably developed by stoping of the country rock during intrusion of the stock.

Monzonite is essentially massive and mostly medium grained, but the grain size can vary from fine to coarse. The colour of fresh and weathered surfaces varies from purple through pink to grey. The weathered surfaces locally have pitted weathered surfaces due to weathering out of the feldspars. The monzonites are composed of variable but approximately equal amounts of sodic to intermediate plagioclase (albite-oligoclase) and alkali feldspar (microcline, possibly minor orthoclase, perthite, and antiperthite) + augite ± biotite ± hornblende, rare quartz, chlorite, and carbonate, and accessory apatite, iron-titanium oxide, zircon, sphene, and hematite. Only normative foids are reported.

A partial ring of pyroxenite is exposed on the southwestern border of the stock, varies in width from 200 to 400 m, and is faulted off at both ends. Pyroxenite consists of augite fringed by uralite, biotite, carbonate, plagioclase (minor), orthopyroxene (Rodgers 1964), and accessory apatite and magnetite. The pyroxenite is dark green to black, medium grained, and has a soft pitted weathered surface. There would appear to be a gradation from pyroxenite on the outer margin to gabbro, and finally to melanocratic monzonite.

Pyroxenite and gabbro dikes mainly cut the granitoid country rock along the western margin of the stock.

Table 10 presents the major and trace element chemistry for 17 samples of this complex. All samples are olivine normative except for two samples of pegmatite (H3-18, H3-19). Similarly, except for these two samples and sample H3-2, all samples are nepheline normative. Figure 14 illustrates the predominant alkalic nature of this body. Only the two pegmatite samples contain normative quartz.

Figures 13 and 14 suggest that the pyroxenite and syenite were possibly derived from the same parental magma by a process of fractional crystallization and gravitational settling.

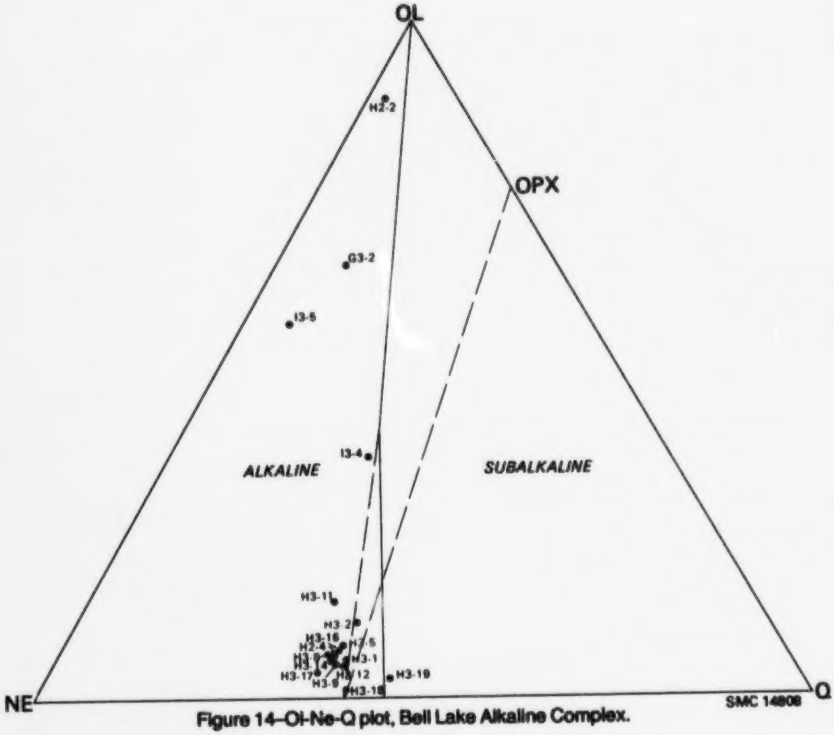

Figure 14–Ol-Ne-Q plot, Bell Lake Alkaline Complex.

Age Relationships of the Felsic to Intermediate Intrusive Rocks

The relative ages of the intermediate to felsic intrusive rocks are generally inferred because the various intrusions are spatially separate.

The epizonal intrusions are considered to be subvolcanic intrusions, and as such are probably among the oldest intermediate to felsic intrusions in the area.

Batholithic emplacement was probably synchronous with the development and subsequent deformation of the volcano-sedimentary belt, and thus could have encompassed a considerable time span. Gneissic structured trondhjemitic enclaves in the Eastern Batholithic Complex are older than the later phases. Since these were deformed prior to incorporation in the younger granitic phases, they may be considerably older than the later phases. Marginal mafic metavolcanics of the volcano-sedimentary belt have been metamorphosed to the almandine-amphibolite rank of metamorphism by the batholithic complexes. These mafic metavolcanics have also been intruded by phases of the batholithic complexes. In some cases, the contact, however, is presently fault controlled, thus making the overall age relationships somewhat equivocal.

The Syenite-Monzonite-Granodiorite Intrusions have apparently been emplaced along a synformal downwarp in the volcano-sedimentary belt. If these intrusions are of anatectic origin, as suggested by the author, emplacement was probably synchronous with, and in fact a result of, this downwarping episode.

The age of the marginal granodiorite-trondhjemite plutons is somewhat equivocal. Internal faulting and modification of the outline and internal foliations of the marginal mafic metavolcanics indicate that the Penassi Lake Pluton was emplaced at a late to post-tectonic stage. The North Arm and St. Anthony Plutons intrude basal mafic metavolcanics of the North Sturgeon Lake and Northeast Arm Assemblages. Field relationships indicate that these plutons also intrude the Western Batholith Complex. The author has previously suggested (*see* "Clastic Metasediments", this report) that arkose of the East Bay metasediments, possibly the youngest volcano-sedimentary sequence of the belt, was partly derived by erosion of the North Arm Pluton. Both the North Arm and St. Anthony Plutons occur as equigranular to slightly porphyritic magmatic protrusions into the volcano-sedimentary belt. These plutons also have associated gold mineralization. In the case of the North Arm Pluton, the gold mineralization is of the hydrothermal vein type possibly superimposed on volcanic stratigraphy. The gold mineralization associated with the St. Anthony Pluton (St. Anthony Mine) possibly resulted from the upgrading of an original stratiform gold occurrence by hydrothermal activity during the emplacement of the St. Anthony Pluton. It is possible that both plutons are intrusions emplaced at relatively high crustal levels during an intermediate stage of greenstone belt development (Elbers 1974). The intermediate to felsic pyroclastic material situated south of the North Arm Pluton may or may not be comagmatic with the intrusion of this pluton.

Intrabelt granodiorite plutons have modified the fold pattern of the volcano-sedimentary belt indicating these plutons were emplaced after the initial deformation of the belt, but probably were emplaced prior to final consolidation. These bodies are compositionally similar to phases within the bordering batholiths. This fact, and their marginal position, suggest these plutons may be continuous at depth with, and perhaps consanguinous with, some phases of the batholithic complexes.

Field relationships, and analogy to other Early Precambrian terranes (Ayres 1974), where the younger granitoid plutons become increasingly more potassic, permit the author to consider that the quartz monzonite and alkalic intrusions are the youngest intermediate to felsic intrusions in the area.

Stratigraphy of the Sturgeon Lake Volcano-Sedimentary Belt

SOUTH STURGEON LAKE ASSEMBLAGE

The author has interpreted the South Sturgeon Lake Assemblage (*see* Figure 2) to consist of four volcanic cycles. From oldest to youngest these are: (1) the Darkwater Lake Cycle; (2) the Claw Lake Cycle, (3) The Lyon Lake Cycle;

and (4) the South Shore Cycle (Figure 15, Chart A, back pocket). Table 11 presents attempts to elucidate the stratigraphy of the South Sturgeon Assemblage by: Franklin (1975), Shegelski (1976), Franklin (1977), and Franklin and Gibb *et al.* (1977), and Trowell (1978).

Darkwater Lake Cycle

The Darkwater Lake Cycle comprises three formations; Formation A, Formation B, and Formation C. The formations have been designated alphabetically for reasons similar to those outlined by Ayres (1977).

Formation A comprises a laterally extensive mafic metavolcanic sequence. Massive flows predominate, and rare finely amygdaloidal and minor porphyritic flows are also present. Pillowed flows occur near the top. Minor fragmentals occur south of the Beidelman Bay Pluton. Several local hiatus levels in the volcanism are marked by locally extensive wacke-siltstone units which occupy interflow positions. These units are locally ferruginous containing minor pyrite and pyrrhotite. Fragmental zones of autoclastic origin occur towards the top of Formation A. All the features observed indicate initial deep water outpourings of tholeiitic basaltic lava that initiated development of a broad basaltic shield volcano.

Two types of gabbro-diorite intrude Formation A. The first type is composed of synvolcanic hypabyssal dikes and sills that have an homogeneous chemistry and textures similar to the mafic flows. The second type is mainly found west of Highway 599 where they occur as large subcircular to elliptical bodies. These bodies are composed of several intrusive phases varying from anorthosite to pyroxenite in composition, for example the Pike Lake Pluton. Locally, they exhibit a cumulate structure defined by alternating feldspathic and ultramafic bands. Intrusive breccia zones consist of volcanic and sedimentary clasts set in a gabbroic matrix. Thin sections from the interior of these bodies contain relic calcic plagioclase and pyroxene (augite). These solidified bodies may represent the solidified magma chambers from which the volcanic flows were erupted.

The Beidelman Bay Pluton intrudes Formation B. Its position approximately separates the lower mafic flow sequence (Formation A) from the upper fragmental sequences (Formations B and C). This pluton could have occupied its present observed position prior to the development of Formation C, and acted as a heat source in the generation of the hydrothermal system that formed the volcanogenic massive sulphide bodies of Formations C and E.

The contact between Formations A and B is transitional. It is marked by a decrease in the amount of flow material and an increase in the amount of pyroclastic and debris flow deposited material. The transition possibly signifies a change from basaltic shield volcanism to the build-up of a strato-volcano.

Formation B consists of intermediate volcanic fragmentals that are predominantly of autoclastic and hyaloclastic origin at the base, to predominantly redeposited and possibly reworked material of pyroclastic origin towards the top. Franklin *et al.* (1977) are correct in referring to these rocks as being *sensu stricto* epiclastic in origin. The author believes, however, that the rocks were not derived by erosion of a volcanic terrain, but rather represent redeposition of unconsolidated volcanic fragmental rocks. A mixed provenance is suggested by the bimodal nature of these fragmentals, specifically felsic clasts in a mafic matrix. Franklin (1976) has separately analyzed the fragments and matrix. Data [plots not shown in this report] on a cation plot (Jensen 1976) indicate that the clasts are calc-alkalic; the matrix tholeiitic, thus complicating any interpretation of possible provenance.

These fragmental rocks are locally bedded, and infrequently show graded bedding. Soft sedimentary slump structures locally occur. Pumice clasts are present, and predominate towards the top of this formation. Local welded structures are probably formed from the weight compaction of these pumice clasts. Locally, a high concentration of pumice clasts suggests the possibility of actual pumice flows.

The size of these fragmental rocks ranges from tuff to pyroclastic breccia, but averages the size range found in lapilli-tuff to lapillistone tuff. The clasts are monolithic to slightly heterolithic because intermediate and mafic clasts locally accompany the dominant felsic clasts. The clasts are generally matrix-supported.

Thin mafic flows are intercalated within the fragmental units. These are generally amygdaloidal and locally pillowed. Commonly, the flows are schistose and highly carbonatized. Some of these mafic units, specifically those west of and beneath the Mattabi Mines Limited orebody, could be synvolcanic sills and feeder dikes for Formation D.

Formation B appears to have been deposited by subaqueous debris flows, the water depth is indicated by an increase in amygdule size. The number of amygdules show a relative decrease from bottom to top. The initial formation of these amygdules was probably by phreatomagmatic explosive volcanism in a shallow water to subaerial environment.

Formation B could have been the source of the metals of the massive sulphide deposits. Hot aqueous solutions could have readily circulated through this formation and could leach the required metals from both the matrix and clasts. As C.J. Hodgson and J.W. Lydon (1977) pointed out, the main requirements for a hydrothermal system are; a heat source, an aquifer zone, a caprock unit, and recharge and discharge channels. The Beidelman Bay Pluton and Formation B satisfy the first two requirements. The anomalous chemistry of Formation B, (*see* section on "Chemistry: South Sturgeon Lake Assemblage", and Table 11) could indicate that a self-sealing cap was formed as a result of the boiling of the discharge fluids as they rose through the fragmental pile comprising Formation B (Hodgson and Lydon 1977). Similarly, some of the intercalated flows could have acted as relatively impermeable barriers further confining the fluids circulating through the aquifer. Formation C could represent the phreatic and phreatomagmatic eruption products that would result from the boiling of these discharge fluids.

Formation C consists of felsic to intermediate fragmentals. The footwall breccia of the Mattabi Mines Limited massive sulphide deposit is a monolithic clast-supported pyroclastic breccia-sized unit. Its monolithic nature and low percentage of matrix indicate that this formation may have been produced by fragmentation of a felsic dome, possibly by phreatic explosive activity as has already been speculated on. The hanging wall material is similar, but consists mainly of finer massive tuff.

Chert bands occur in both the hanging wall fragmental rocks and as a thin unit separating the upper and lower orebodies (Franklin *et al.* 1977). For a thorough description of the geology of the immediate mine area, the reader is referred to Franklin *et al.* (1975, 1977).

Claw Lake Cycle

The Claw Lake Cycle comprises two formations (Formations D, E).

Formation D is composed of massive, feldspar porphyritic, and pillowed, amygdaloidal flows containing coarse amygdules with minor tuff and autoclastic/hyaloclastic breccia. J.M. Franklin and W. Gibb *et al.* (1977) reported an intercalation of mafic flows and tuff with felsic tuff (Formation C) at the base of Formation D:

Pillowed flows compose the lower part of Formation D. These flows are composed of pillows up to 3 by 0.7 m in size, and averaging 1.2 by 1 m in size. These pillows have a contorted squeezed appearance probably produced by primary deformation. They are also strongly foliated. They grade into apparent isolated pillow breccia. Tops are to the north. Pillow selvages are extremely thick, up to 10 cm, but averaging 2.5 cm. Epidotic alteration is prevalent. Subophitic-textured massive flows or sills are intercalated with the pillowed flows.

Mafic, locally carbonatized, crystal tuff layers near the base of Formation D are locally graded with tops to the north. The feldspar porphyritic flows are also confined to the base of Formation D where they are accompanied by medium-grained, magnetic, massive flows or sills. Massive flows comprise the majority of the upper part of Formation D.

Franklin and Gibb *et al.* (1977) reported that thin chert and graphitic shale units are intercalated with the flows of Formation D.

Formation D thins rapidly to the east, pinching out west of Lyon Lake (Franklin *et al.* 1977) suggestive of a possible source or vent area to the west.

A shallow water environment of deposition is indicated by: 1) the thick selvages plus the coarsely amygdaloidal nature of the pillows (Jones 1969); 2) explosive pyroclastic debris indicative of formation in water depths less than 500 m (McBirney 1953); and 3) possibly, the graphitic nature of the interflow mudstones.

Formation E consists of intermediate to felsic fragmental rocks that range in particle size from pyroclastic breccia to ash tuff. This formation has been subdivided by Franklin and Gibb *et al.* (1977) into a lower breccia member and an upper tuff member respectively.

The coarse fragmental units consist of angular to rarely subrounded felsic clasts set in a fine tuff matrix. Both quartz and feldspar porphyritic clasts are present within the breccia unit. Pumiceous or vesiculated (Lorrentz 1974) tuffs are locally present. This feature, coupled with the coarse clast size and the local paucity of the matrix, probably suggests a shallow water environment of formation. Phreatomagmatic explosive activity with autoclastic fragmentation of a felsic dome probably took place.

The breccia unit is similar to the host rocks of the Mattabi Mine area and is interpreted by Franklin and Gibb *et al.* (1977) as a continuation of Formation C-type volcanism albeit from a different volcanic source. In the Mattabi Mine area, the average clast size decreases to the west. Franklin and Gibb *et al.* (1977) reported that in the Lyon Lake area, Formation E has a domal configuration being composed of abundant coarse felsic breccia with thin discontinuous shale units. This implies that two separate centres of volcanism existed in the area of the Mattabi Mine and in the area of Lyon Lake respectively. These breccia units are crudely stratified. Apparent normal grading indicating tops to the north, was observed northeast of the Mattabi Mine.

The upper felsic tuff unit is poorly exposed. Franklin and Gibb *et al.* (1977) reported as follows:

> . . .at least four distinct, laterally extensive graphitic shale beds occur in the lower 1600 feet.
>
> The distinctive graphitic shale beds noted above Mattabi terminate below the Lyon Lake deposits, possibly cut off by an unconformity.
>
> The rhyolite unit at the Lyon Lake and Creek Zone deposits is capped by a thin massive lens of tuff-wacke, probably derived by fragmentation of adjacent felsic volcanic rocks. This lens pinches out before reaching the more easterly Falconbridge deposit.

A gabbro intrusion, with marked high magnetic relief, is situated within the footwall rhyolite at the Falconbridge and Lyon Lake deposits. Franklin and Gibb *et al.* (1977) reported that:

> It is very similar to the dyke-sill complex west of Mattabi and possibly is also a subvolcanic sill, representing part of the feeder system to the cycle 2 basal mafic unit.

Franklin's cycle 2 basal mafic unit is equivalent to the author's Formation F, the Lyon Lake cycle.

Lyon Lake Cycle

The Lyon Lake Cycle comprises four formations (F, G, H, and I). Formation F comprises a basal mafic flow sequence with possible intrusive equivalents. It overlies felsic to intermediate fragmentals of Formation E, but the nature of the contact is not known. Only a few scattered exposures of this unit outcrop south of Lyon Lake.

Two exposures of Formation G are present in the bay at the entrance to Bell Creek. These rocks consist of fine-grained, finely quartz porphyritic, massive homogeneous felsic volcanic rock. A minor amount of fragmentation is possibly of autoclastic origin. The homogeneous texture and regular polygonal joint fracture pattern suggests these exposures may be of flow or intrusive origin.

Formation H consists of intercalated mafic to intermediate flows with minor tuffs and felsic fragmental rocks. Highly carbonatized, schistose, pillowed, and amygdaloidal flows were recognized. Thin beds of lithic-crystal mafic tuff occupy an interflow (?) position. Intercalated felsic fragmental rocks are carbonatized and schistose. A coarse intermediate to felsic tuff breccia zone was observed on the shore of Sturgeon Lake containing up to 0.3 by 1.2 cm spindle-shaped intermediate clasts. This unit is matrix-supported and shows apparent reverse grading indicative perhaps of deposition by debris flow proximal to source.

Formation I comprises a clastic metasedimentary sequence of wacke, mudstone and siltstone, conglomerate, and carbonaceous sulphidic mudstone. Minor mafic tuff is locally present. This metasedimentary sequence has been extensively described by P.E. Nielson (1974) which has been designated by him as the "Claw Lake-Lyon Lake Graphite Sulphide Formation". The following description is summarized from his thesis (Nielson 1974).

Thinly bedded black graphitic mudstone and light grey siltstone, intercalated with wacke, show planar tops and bottoms and soft-sediment deformation features. Massive wacke is lithic to feldspathic; the lithic component comprises felsic and mafic volcanic clasts. Sedimentary features include; minor ripples and flaser structure, rare graded bedding, and possible convolute lamination.

Matrix-supported conglomerate lenses contain subangular to subrounded clasts that average 1 cm in maximum dimension. The clasts are predominantly of felsic volcanic rocks and minor feldspar porphyry, intermediate to felsic volcanic rocks; and graphitic shale chips.

The carbonaceous sulphide zone is found mainly in a shale host. It consists of carbonaceous material, pyrite and pyrrhotite with minor amounts of arsenopyrite, chalcopyrite, sphalerite, and magnetite.

Nielson (1974) concluded that this sequence had a volcanic-sedimentary basinal origin, and a volcanic centre existed to the west. An eastwards deepening of the basin occurred during deposition of the finer grained turbiditic sediments.

This sequence is indicative of a substantial hiatus in volcanism. The water level was of moderate depth, as suggested by the presence of amygdaloidal flows below and above (Formation J) this sequence. There was probably a complex interplay between water depth and sinking and rising of the volcanic pile.

Franklin (1977) referred to possible welded tuff units at the top of this cycle that are suggestive perhaps of subaerial ignimbritic activity. Collapsed pumice can form by compaction, and considered alone is neither a criterion for welded tuff nor for subaerial volcanism.

South Shore Cycle

The South Shore Cycle comprises five formations (J, K, L, M, N).

Formation J consists of massive, pillowed, and amygdaloidal flows. The pillows are up to 3.0 m by 0.7 m wide, but may be tectonically elongated. The amygdules are up to 2 cm in diameter. The flows are schistose and have been carbonatized. The most western exposure of the formation is cut by fine-grained mafic synvolcanic dikes, 0.3 to 1.5 m wide spaced every 3 to 8 m. These dikes could indicate a position near a vent. An interflow fragmental unit from this same exposure contains elongated, feldspar porphyritic, mafic, volcanic clasts set in a fine-grained tuffaceous matrix. It exhibits apparent reverse grading at its base and has a probable redeposited pyroclastic/autoclastic origin.

Wacke, and carbonaceous and sulphidic mudstone (Franklin and Gibb *et al.* 1977; Palonen and Speed 1977) comprise Formation K. Formation K has a restricted distribution and was probably laid down in a shallow marine environment. The beds of mudstone and carbonaceous mudstone are also interbedded in the basal part of Formation L, indicating an overlap in time of quiescent sedimentation and vigorous calc-alkalic volcanism. Clasts of graphitic mudstone, and sulphidic mudstone occur in the upper units of Formation L indicating that as volcanism continued, Formation K became emergent and subject to active erosion.

The intermediate to felsic fragmental rocks of Formation L are *sensu stricto* epiclastic in origin because they show evidence of being redeposited, albeit from a proximal source. The origin of these rocks was probably related to pyroclastic and perhaps autoclastic volcanic activity in a shallow water to subaerial environment. Fine-grained mafic volcanic dikes that cut Formation L could be feeders for the overlying mafic flow sequence (Formation M). These dikes may also imply an eastwards migration of the vent area with respect to Formation J.

The fragmental rocks consist of tuff- to pyroclastic breccia-sized, matrix- to locally clast-supported, lensoid accumulations of volcanic detritus. The clasts are subrounded to subangular, and are predominantly felsic to intermediate in composition. Texturally, these clasts vary from aphanitic to medium grained with both quartz and quartz-feldspar porphyry varieties being present. Intermediate amygdaloidal clasts have the appearance of detached pillows or pillow fragments that have been incorporated in the fragmental units. The matrix is crystal-lithic tuff. Sedimentary structures observed in these fragmental rocks include scour channels, rare ripple marks, soft-sediment deformation, graded bedding (normal and rarely, reverse), and crossbedding. Local fragmental units that are 20 m thick appear to have been deposited in sub-units akin to an A(B)CD Bouma unit. Franklin (1975), Shegelski (1976) reported the presence of pumice fragments and fiamme within Formation L; this presence is suggestive of subaerial ignimbritic-type volcanism.

Features interpreted to support subaerial volcanism are;

(1) The large amygdules present in the pillowed flow of Formations J and M;

(2) The presence of scour channels, detached pillows, and clasts of Formation K in Formation L;

(3) Franklin's (1975) and Shegelski's (1976) observations. Formation L may have originated by build-up of a locally emergent fragmental pile (caldera-collapse facies?) followed by later movement of this material, as debris to turbidity flows, down a steep palaeoslope onto the sea floor.

Formation M is composed of massive, pillowed, amygdaloidal, and finely feldspar-porphyritic mafic volcanic flows. Exposure is limited, but Formation M appears to have a restricted distribution. The flows are schistose and locally carbonatized; carbonate fills tension gashes characteristically developed in the flows of this unit. These tension gashes may have formed by movement along the postulated, southeastwards extension of the Sturgeon Narrows 'Cataclastic Zone'. Minor interflow fragmental units consist of fine-grained intermediate volcanic clasts set in a fine-grained matrix. These units could be of autoclastic or hyaloclastic breccia origin. This formation represents the last episode of volcanism in the buildup of the South Sturgeon Lake Assemblage which was probably a strato-volcano.

A clastic metasedimentary formation (Formation N) overlies the South Sturgeon Lake Assemblage. Table 15 A presents chemical analyses of these metasediments. The formation consists of debris flows, conglomerate, wacke-siltstone, and minor quartz-magnetite ironstone. The debris flows, conglomerate, and thickly bedded wacke-siltstone exposed in the central part of the Sturgeon Lake Belt represent proximal accumulations. The more thinly bedded wacke-siltstone units in the Princess Lake-Quest Lake area comprise distal material deposited by turbidity currents in a progressively downsinking basin. The individual volcanoes of the area were no doubt emergent at this time and were subject to active erosion. The presence of mafic to intermediate tuffaceous material and discrete beds in the wackes that extend southeastwards from Post Lake are indicative of continuing volcanism (subaerial?).

Formation N extends almost 40 km to the east, but west of Sturgeon Lake, it appears to pinch out or to have been removed by later faulting. In the east, the formation disconformably overlies the originally gently dipping flanks of the South Sturgeon Lake strato-volcano. In the central part of Sturgeon Lake, there is an angular discordance between the trend of Formation N and the formations that compose the central and western parts of the strato-volcano. This is to be expected if active erosion of an emergent volcano, composed of extensive fragmental material was occurring. The coarse clastic material that would accumulate in a proximal position on the flanks of such a volcano would have an angle of repose, not necessarily horizontal. This angle would no doubt have been shallower than the volcanic palaeoslope, thus producing an initially small angular discordance. The angle of repose would tend towards the horizontal and produce the marked angular discordance presently observed. Relative emergence and subsidence of the volcanic pile and sedimentary basin respectively, can account for the relationships without accompanying tectonic movement.

Shegelski (1976) subdivided the debris flows, or the volcaniclastic breccias as he referred to them, into two major groups dependant on whether mafic or felsic volcanic clasts were more abundant. These groups consist of redeposited, poorly sorted, unstratified and ungraded, clast-supported lenses of coarse volcanic detritus. The clasts are angular to subrounded in shape and are composed predominantly of mafic and felsic volcanic material with minor shale, chert, jasper, carbonaceous mudstone, and quartz. Quartz clasts would have been derived from quartz veins. Sulphidic mudstone clasts are locally present and compose up to 5 percent of the rock.

The conglomerate units contain rounded to well-rounded clasts, are variable from clast- to matrix-supported, and occur in lensoid accumulations commonly separated from each other by wacke-siltstone interbeds that define the stratification. Local quartz-feldspar trondhjemite porphyry clasts, were probably derived by the erosion of hypabyssal intrusions. Reverse graded bedding was reported (personal communication from P.A. Palonen, formerly Resident Geologist, Ministry of Natural Resources, Sioux Lookout, 1975) in shaly wacke of Formation N, situated west of Barge Lake. This is an unusual occurrence in such fine-grained clastics.

Quartz-magnetite ironstone occurs on one island in the central part of Sturgeon Lake. The pronounced aeromagnetic and ground magnetic (Barlow 1975a and b) highs that extend down the central part of Sturgeon Lake, and the Barge-Post-Add-Willet chain of lakes, probably reflect the presence of similar ironstone units. Rodgers (1964) has described this member in some detail, including a study of its economic potential of a part of the eastwards continuation of this member. The great lateral extent of this member indicates a rather stable period of quiescent sedimentation.

Formation N is composed almost completely of volcanic detritus, which is predominantly intermediate and felsic in composition. The likely sources for this detritus are the felsic to intermediate fragmental rocks of the South, and North Sturgeon Lake Assemblages. Since the majority of these fragmental units are of calc-alkalic affinity, any consideration of the relative abundance of magmatic rock suites within the area will be biased towards the mafic flows of tholeiitic composition. This situation is likely to be true for other areas where variable amounts of calc-alkalic volcanic rocks have been eroded to form intravolcanic clastic sedimentary sequences.

Petrochemistry of the South Sturgeon Lake Assemblage

Chemical data of the South Sturgeon Lake Assemblage are presented in Tables 12, 13, 14, 15, and Figures 16 and 17 inclusive. Descriptions and interpretations of the chemistry of this assemblage by Franklin (1975, 1977) and Franklin and Gibb *et al.* (1977) and Franklin, Kasarda, and Poulsen (1975) are included in the present discussion. The author's data for the Lyon Lake and South Shore Cycles are probably insufficient for any meaningful discussion of petrogenesis to be made. These cycles are therefore not discussed herein except for the comments of Franklin and Gibb *et al.* (1977).

The metavolcanic flows of the Darkwater Lake and Claw Lake Cycles appear to be mixed tholeiitic and calc-alkalic rocks. The intermediate and felsic fragmental rocks are mixed tholeiitic and calc-alkalic rocks, but the trend is for lower units to be predominantly tholeiitic rocks, and upper units to be calc-alkalic rocks.

Mafic flows and fragmental rocks extend along the south shore of Sturgeon Lake from north of the Darkwater Mine westwards to the southwest end of Sturgeon Lake. These units are dominantly calc-alkalic basalts. To the east, these rocks are intercalated with, and overlain by, dominantly tholeiitic fragmental rocks.

Formation D, the lowermost mafic flow sequence of the Claw Lake Cycle, is dominantly tholeiitic basalt and andesite.

Other mafic flows of these two cycles are variably tholeiitic or calc-alkalic, but are also more extensively altered than the above two chemically homogeneous units. Mafic intrusions of the Claw Lake Cycle plot in the tholeiitic basalt field of the AFM diagram and Jensen Cation plot.

Franklin and Gibb *et al.* (1977, p.14) reported that:

> In cycle 1 [author's combined Darkwater Lake and Claw Lake Cycles] 55 percent of the rocks belong to the tholeiitic group, 45 percent to the calc-alkalic group. Rocks within the felsic subgroup of this cycle show a distinct change upwards through the cycle, moving from 63 percent tholeiitic in cycle 1A [author's Darkwater Lake Cycle] to 60 percent calc-alkalic in cycle 1B [author's Claw Lake Cycle].

The major problem in interpreting the petrochemistry of these two cycles is the effect of alteration. The alteration is intense in the vicinity of the massive sulphide deposits (Franklin and Gibb *et al.* 1977; Franklin, Kasarda, and Poulsen 1975; Hinzer 1977), but as O.P. Lavin (1976) pointed out, there is also more extensive pervasive alteration away from the deposits as well. Examination of

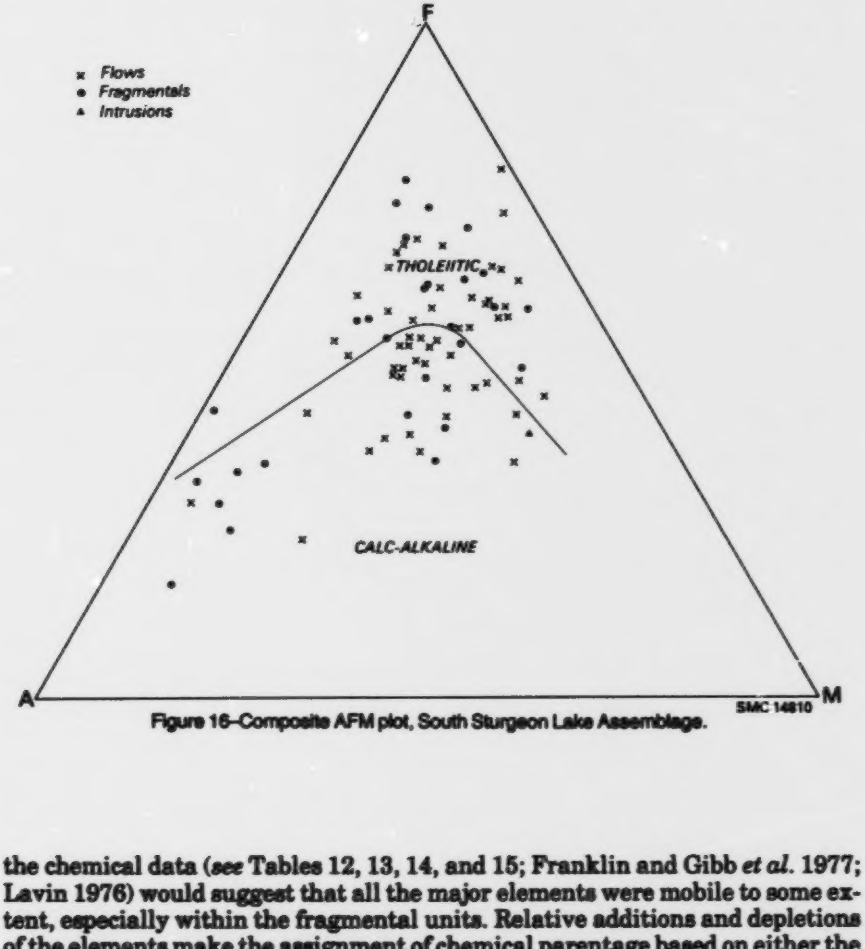

Figure 16–Composite AFM plot, South Sturgeon Lake Assemblage.

the chemical data (*see* Tables 12, 13, 14, and 15; Franklin and Gibb *et al.* 1977; Lavin 1976) would suggest that all the major elements were mobile to some extent, especially within the fragmental units. Relative additions and depletions of the elements make the assignment of chemical parentage based on either the AFM, or Cation Plot somewhat equivocal.

The possibility does exist that the Darkwater Lake and Claw Lake Cycles are representative of only one magma type (tholeiitic?) and that the scatter observed (Figures 16 and 17) reflects fractionation, contamination, and subsequent hydrothermal alteration of the various mafic and felsic to intermediate units.

Chemical data for the Lyon Lake Cycle (Cycle 2 of Franklin and Gibb *et al.* 1977) plot in the tholeiitic basalt field. Franklin and Gibb *et al.* (1977, p.14) indicate that:

> Cycle 2 mafic rocks are 50 percent calc-alkalic, 50 percent tholeiitic. Cycle 2 felsic rocks are 93 percent calc-alkalic, 7 percent tholeiitic.

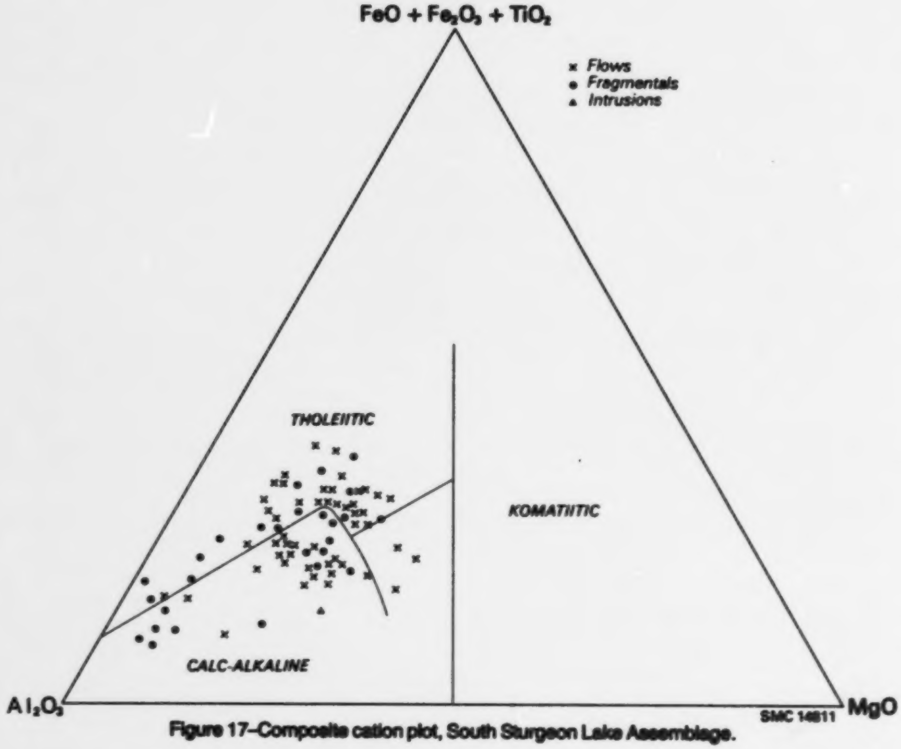

Figure 17–Composite cation plot, South Sturgeon Lake Assemblage.

The South Shore Cycle is composed of mixed tholeiitic and calc-alkalic flows and fragmental rocks. Franklin and Gibb *et al.* (1977, p.14) reported that:

> Cycle 3 [author's South Shore Cycle] mafic rocks are 80 percent tholeiitic.

Franklin and Gibb *et al.* (1977, p.14) interpreted the evolution of the South Sturgeon Lake Assemblage likewise:

> Thus either fractionation or contamination has affected in parallel both rhyolite and basalt-andesite magmas of cycles 1 through 2. Cycle 3 appears to represent a return to more primitive composition, but its felsic component is too inadequately represented to draw further conclusions.

NORTH STURGEON LAKE ASSEMBLAGE

The author has interpreted the North Sturgeon Lake Assemblage to be composed of two volcanic cycles. The oldest and youngest cycles are: (1) the

Fourbay Lake Cycle; and (2) the Jumping Lake-Six Mile Lake Cycle respectively.

Fourbay Lake Cycle

The Fourbay Lake Cycle comprises three formations (Formations A1, B1, C1).

Formation A1 consists of a lower clastic sequence of feldspathic lithwacke, siltstone, minor pebbly wacke, and intercalated mafic flows.

Wacke-siltstone is thinly to locally thickly bedded, and has planar tops and bottoms to its beds. The beds are locally graded and exhibit rare fine crossbedding and convolute lamination. Pebbles of intermediate volcanic material are present in a few beds. Metamorphic amphibole is abundant in the wacke-siltstone. Its presence is suggestive of a mafic volcanic flow/tuff provenance for the sedimentary rocks. Granitic rocks of the Western Granitic Complex have almost completely removed the interpreted eastward extension of these sedimentary rocks. The sedimentary rocks also thin to the east, indicating a possible source area to the west.

Thin, massive, rarely pillowed, volcanic flows are intercalated with the wacke-siltstone units. These rocks are locally porphyritic, containing 5 to 10 percent, fine- to medium-grained, anhedral to subhedral plagioclase phenocrysts. Uncommon autoclastic flow-breccia zones are also present. Lack of vesicularity is suggestive of deepwater formation of these flows.

The sedimentary features and bedding thicknesses, together with the overall massive nature of the flows, indicate deepwater deposition. The sedimentary rocks were probably deposited by turbidity currents in a median position with respect to the source.

Formation B1 is composed predominantly of mafic volcanic flows with minor interflow wacke-siltstone beds. It is essentially the opposite of Formation A1 in its abundance of respective lithologies, and is marked by predominant mafic volcanism with sporadic influxes of turbiditic sediments.

The massive and porphyritic flows of Formation B1 are similar to those of Formation A1, but the plagioclase phenocrysts are more abundant and slightly larger. Non to very finely amygdaloidal pillowed flows are composed of bun-shaped pillows with selvages in excess of 1 cm in thickness. A porphyritic pillowed zone exhibits subhedral altered plagioclase phenocrysts, variable in size from 2 mm to 30 cm. The phenocrysts compose 30 to 50 percent of the interior of the pillows.

In addition to the thin interflow beds of wacke-siltstone, a substantial thick unit of ferruginous wacke-siltstone lies near the top of Formation B1.

A sill of biotite trondhjemite occurs just below this wacke-siltstone unit. It shows a chilled contact with the mafic volcanic flows, but is also cut by fine-grained mafic synvolcanic dikes. These dikes suggest the biotite trondhjemite sill was intruded penecontemporaneously with the outpouring of mafic flows.

Gabbro-diorite sills and dikes intrude this sequence. These rocks are generally massive, medium to coarse grained, and have well-developed joint sets. Feldspar (plagioclase) and amphibole (after pyroxene) porphyritic phases are also present. Fine-grained mafic volcanic dikes also cut the flows.

Formation C1 is composed of intermediate fragmental rocks cut by mafic intrusions similar to those of Formation B1. The fragmental rocks occur in two modes: (1) lapilli tuff-sized, massive to locally graded, very thick to extremely thick beds; and (2) tuff-sized, graded, thin to very thin, locally laminated beds.

The lapilli-tuff sized units contain clasts that average 5 cm in length, and have an elliptical to rounded form. Clasts in excess of 20 cm in length are locally present. The lapilli-tuff sized beds are heterolithic containing fine-grained equigranular, quartz and feldspar porphyry intermediate volcanic clasts, and minor fine-grained mafic volcanic clasts. The tuff-sized beds contain minor lithic clasts set in a matrix of 1 to 3 mm intact and broken subhedral feldspar crystals. These two unit-types could represent different parts of a subaqueous pyroclastic flow unit similar to those described by R.S. Fiske (1963a, 1963b) and R.S. Fiske and T. Matsuda (1964). Specifically, the coarse units could have been deposited by subaqueous debris flows, while the finer units could represent more distal subaqueous debris flow deposition and/or background settling of suspended ash material. The sedimentary structures and bedding thicknesses are comparable to those developed by medial turbidites.

The fragmental units of Formation C1 appear to pinch out to the east. These fragmental rocks and the wacke-siltstone units of Formation B1 have been derived from a more distant source and were deposited during a local hiatus in volcanism. These units may therefore represent only a pause in mafic volcanism, and may not compose the top of a discrete volcanic cycle as the author has suggested.

The basal formations have been isoclinally folded. Local isolated fold closures indicate a second phase of folding coplanar to the first. The wacke-siltstone and mafic flow units are foliated, and locally are schistose. Pronounced schistosity is, however, confined to specific beds and lithologic and flow contacts. Boudinage structures were observed in Formation A1. The mafic flows face predominantly south, and the metasediments face both north and south reflecting the isoclinal folding. The units dip predominantly north indicating a major overturn of the lower part of the North Sturgeon Lake Assemblage has occurred.

Jumping Lake-Six Mile Lake Cycle

The Jumping Lake-Six Mile Lake Cycle comprises two formations (Formations D1, E1).

Massive and pillowed flows, minor porphyritic flows, and narrow hyaloclastic and autoclastic breccia zones comprise the lower mafic flow sequence (Formation D1). The pillows are irregularly shaped and have 2.5 cm or greater, thick selvages. The amygdules increase in size to the south, suggestive of a decreasing water depth at the time of formation. The flows are thicker than in the Fourbay Lake Cycle, the thickness is 10 to 25 m versus 5 to 10 m respectively. Silicification with minor pyrite occurs along flow contacts. The flows are cut by feldspar porphyry and equigranular trondhjemite dikes.

Autoclastic flow breccia (3 m wide) and two zones of amygdaloidal pillow breccia (more than 5 m in width) compose the upper zones of one massive and two pillowed flows respectively. Several more such zones are probably present, but are either not exposed, have been eroded from the exposed outcrop, or are represented by non-penetrative chlorite schist zones.

The porphyritic flows contain subhedral plagioclase phenocrysts that vary in size from 1 to 30 mm, and average 4 mm in size. The phenocrysts compose 5 to 10 percent of the flow/flow zone. These flows are thinner than the massive and pillowed flows, and are on the order of 5 to 10 m thick.

The gabbro-diorite, and fine-grained volcanic intrusions are similar to those of the Fourbay Lake Cycle.

The intermediate to felsic fragmental rocks that constitute the upper part of the Jumping Lake-Six Mile Lake Cycle (Formation E1) have been subdivided into three main types: (1) autoclastic breccia; (2) pyroclastic and redeposited pyroclastic detritus; and (3) conglomerate and wacke-siltstone.

A volcanic breccia unit situated north of Six Mile Lake is characterized by being monolithic, clast-supported, and containing angular clasts with a very small matrix component. This unit could represent a proximal near-vent autoclastic breccia facies with the detritus having been produced by the mechanical fragmentation of volcanic flows and/or domes.

The autoclastic unit is bounded by, or shows a facies change to, pyroclastic and redeposited pyroclastic detritus. The pyroclastic fragmental rocks occur in thin to very thick locally graded beds. The coarsest size fractions are found north of Six Mile Lake with the average clast-size decreasing both to the east and west. These units are similar to the upper fragmental sequence of the Fourbay Lake Cycle (Formation C1). Such units may have been deposited by subaqueous pyroclastic flows with the volcanic detritus being supplied by phreatomagmatic volcanism from a central vent area situated north of Six Mile Lake.

To the west in the Cobb Bay and Handcuff Lake area, there is an apparent westwards facies change from redeposited pyroclastic material to conglomerate with interbedded wacke-siltstone to thinly-bedded wacke-siltstone in contact with the bordering granitic rocks. Volcanic breccia units intercalated with the conglomerate reflect concomitant volcanism and sedimentation. The conglomerate consists of subrounded to subangular volcanic clasts set in a coarse sand-sized lithic wacke matrix. The individual beds are graded, locally show reverse grading at the base, are poorly sorted, matrix- to clast-supported, and exhibit apparent clast imbrication and uncommonly, cross-lamination. The clasts are dominantly felsic to intermediate in composition, but some intermediate and mafic clasts are present. Possible accretionary lapilli structures suggest a shallow water environment of deposition. Wacke-siltstone interbeds in the conglomerate locally exhibit scours, shale rip-ups, and fine cross-stratifications. The conglomerate grades westward into pebbly wacke and finally thinly-bedded distal wacke-siltstone turbidites. The structures observed in the conglomerate suggest these rocks are shallow water proximal turbidite deposits, but the wacke-siltstone units in the west represent a more distal facies probably deposited under deeper water conditions.

Chert horizons are locally present in the pyroclastic and redeposited pyroclastic rocks south of Six Mile Lake. Thin mafic tuff beds are also present. The mafic tuff beds could represent settling of suspended mafic ash originally generated by distal air-fall volcanism. To the west, massive and amygdaloidal mafic flows, possibly units of the North Shore Cycle, are intercalated within the clastic metasediments.

Porphyry and felsite intrusions are similar in composition and texture to the fragmental rocks, and are probably comagmatic with the volcanism.

The gabbro-diorite intrusions occur in two modes: (1) as large ellipsoidal or equidimensional bodies on the order of several hundred metres in extent; and (2) as narrow dikes and sills and small irregular pods. Several phases of gabbro-diorite are defined by contrasts in grain size and texture. In general, medium- to coarse-grained, equigranular, gabbro-diorite is cut by later feldspar porphyry to anorthositic gabbro-diorite. Fine-grained to aphanitic intrusive phases are also present. These gabbro-diorite masses could represent the hypabyssal equivalents, and could have been the feeder dike system for the North Shore Cycle of mafic volcanism.

T.H. Dusanowskyj and G.F. West (1976), in their gravity modelling studies of the North Sturgeon Lake Assemblage, found that the maximum depth to the bottom of this assemblage is 4.5 km. This figure contrasts with an apparent measured thickness of 8 km (Beggs 1975) or close to 12 km if measured from the base southward to the synclinal structure extending through Sturgeon Lake (this report). Dusanowskij and West (1976) presented three interpretations to explain the discrepancy in thicknesses: (1) a change in density with depth; (2) the roots of the volcano-sedimentary belt have been "torn away"; and (3) there is considerably more folding, much tighter than was mapped.

B.E. Gorman *et al.* (1978) suggested that thrusting in the marginal areas of volcano-sedimentary belts may lead to significant tectonic thickening.

The following new observations (this report) tend to reduce the apparent measured thickness: (1) isoclinal folding in the lower 3 to 4 km of sedimentary rocks and metavolcanics; (2) the lower 3 to 4 km commonly shallow dip is predominantly north into the surrounding granitoid terrain; (3) the volcano-sedimentary belt is in fault contact with the northern granitoid terrain; and (4) dips for the upper 9 km average 70 degrees. These observations, however, cannot by themselves explain the discrepancies in apparent thickness and gravity-modelled thickness. Non-penetrative shear zones were noted in the volcanic rocks, but no major decollements were observed by the author. No repetition of the stratigraphy was observed, but the flows are so monotonous in respect to both physical features and chemistry, that it is doubtful whether tectonic thickening could be detected on this basis. It is possible that the upper felsic fragmental rocks of the Jumping Lake-Six Mile Lake Formation could have been structurally emplaced by thrusting or gravity sliding onto the lower, predominantly tholeiitic mafic flow sequence. This is reflected in the sharp change in the following: chemistry (tholeiitic to calc-alkalic volcanism) and the nature of the volcanism, (flows to fragmental rocks).

Petrochemistry of the North Sturgeon Lake Assemblage

Chemical data of the North Sturgeon Lake Assemblage are presented in Table 16 and Figures 18 to 24 inclusive.

The chemical data of D. Beggs (1975) has been used to present the petro-

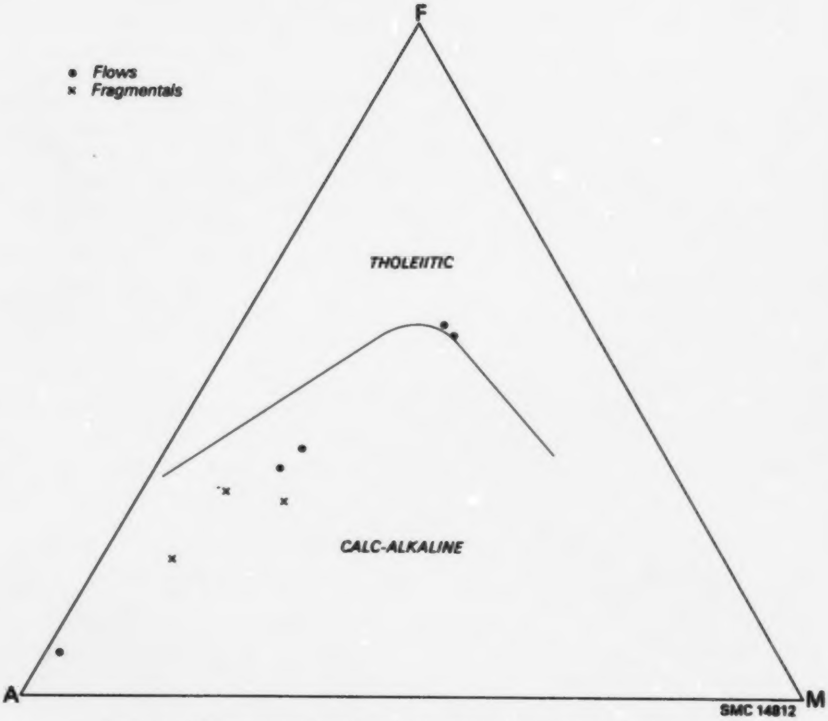

Figure 18–AFM plot, North Sturgeon Lake Assemblage, Highway 599 area.

chemistry of the North Sturgeon Lake Assemblage. Table 16 and Figures 18 and 19 give details on rock units in the area of Highway 599.

On a Cation Plot (Jensen 1976), the mafic metavolcanics of the Fourbay Lake Cycle (Formations A1, B1) and Jumping Lake-Six Mile Lake Cycle (Formation D1) plot in both the high-iron and high-magnesian tholeiitic basalt fields (Figure 24). Even though analyses of samples from specific stratigraphic sections plot in one or the other of these fields, these rocks (from which the samples were taken) are otherwise intimately interlayered. Figure 24 indicates a relatively small scatter of the data about the division between the high-iron and high-magnesian fields. These flows may therefore represent only one tholeiitic magmatic parentage, the scatter of data being due to initial inhomogeneties in this magma and subsequent alteration of the flows.

Some of the flows within the predominantly tholeiitic mafic metavolcanics plot in the calc-alkalic basalt field. No physical differences were noted during field mapping between these flows and those of tholeiitic affinity. Other rock types of the calc-alkalic suite developed are not developed; only basalts are developed. For these reasons, the author favours the interpretation that these flows are altered tholeiitic flows.

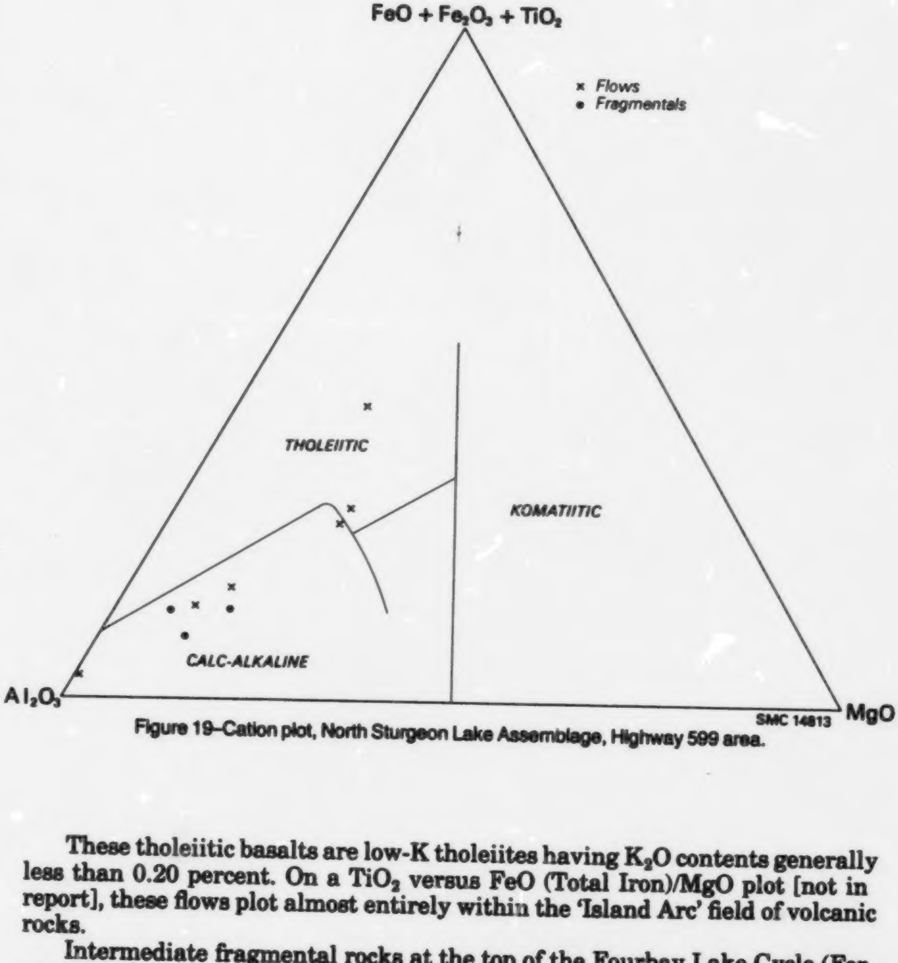

Figure 19–Cation plot, North Sturgeon Lake Assemblage, Highway 599 area.

These tholeiitic basalts are low-K tholeiites having K_2O contents generally less than 0.20 percent. On a TiO_2 versus FeO (Total Iron)/MgO plot [not in report], these flows plot almost entirely within the 'Island Arc' field of volcanic rocks.

Intermediate fragmental rocks at the top of the Fourbay Lake Cycle (Formation C1) plot in the calc-alkalic dacite field. But, as has been discussed previously, the author interprets these units to be redeposited material from a source probably initially located to the west of their present area of outcrop. Too little is known about these units to interpret how their chemistry ties in with the petrochemical evolution of the main part of the North Sturgeon Lake Assemblage.

Analyses of rocks from mafic intrusions that intrude the metavolcanics plot in the tholeiitic field and in a similar manner to the flows. This is indicative of a synvolcanic and comagmatic origin.

Samples from the upper fragmental sequences (Formation E1) of the Jumping Lake-Six Mile Lake Cycle plot in the calc-alkalic field (*see* Figure 24).

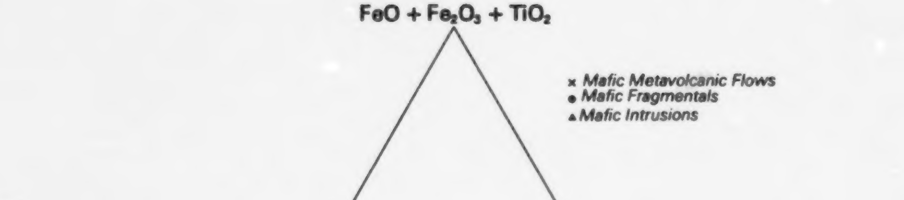

Figure 20–Cation plot, North Sturgeon Lake Assemblage, samples of Begg's 1-25.

These analyses plot predominantly as dacite and rhyolite with minor mafic units plotting as calc-alkalic basalt. Andesite is almost entirely lacking. Mafic intrusions present in this sequence plot in the tholeiitic basalt field. It is uncertain whether these intrusions are synvolcanic equivalents and/or feeders to the mafic flows (Sturgeon Lake Assemblage, Formation A4) that overlie this fragmental sequence; these flows are much more iron-rich than the intrusions.

The mafic flows and intrusions are relatively monotonous both physically and chemically, showing little to no differentiation. Beggs (1975) interpreted these flows as having been derived from a homogeneous source derived by partial melting of the upper mantle. Beggs (1975) interpreted the calc-alkalic fragmental sequence (Formation E1) as having been derived by partial melting of amphibolite produced upon sinking of the basal mafic metavolcanics into an area of high heat flow.

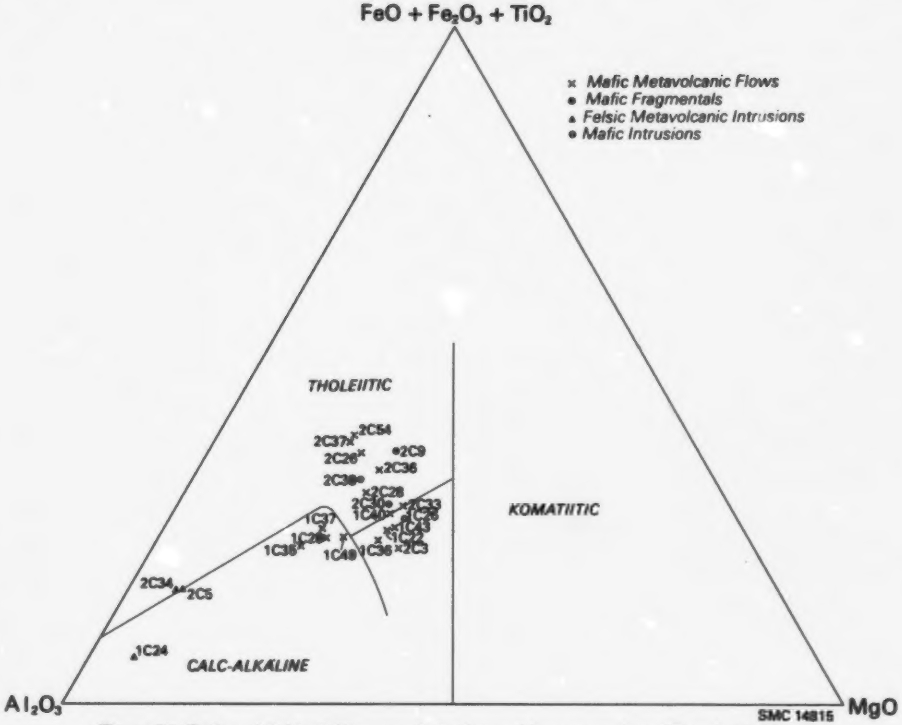

Figure 21–Cation plot, North Sturgeon Lake Assemblage, samples of Begg's 25-50.

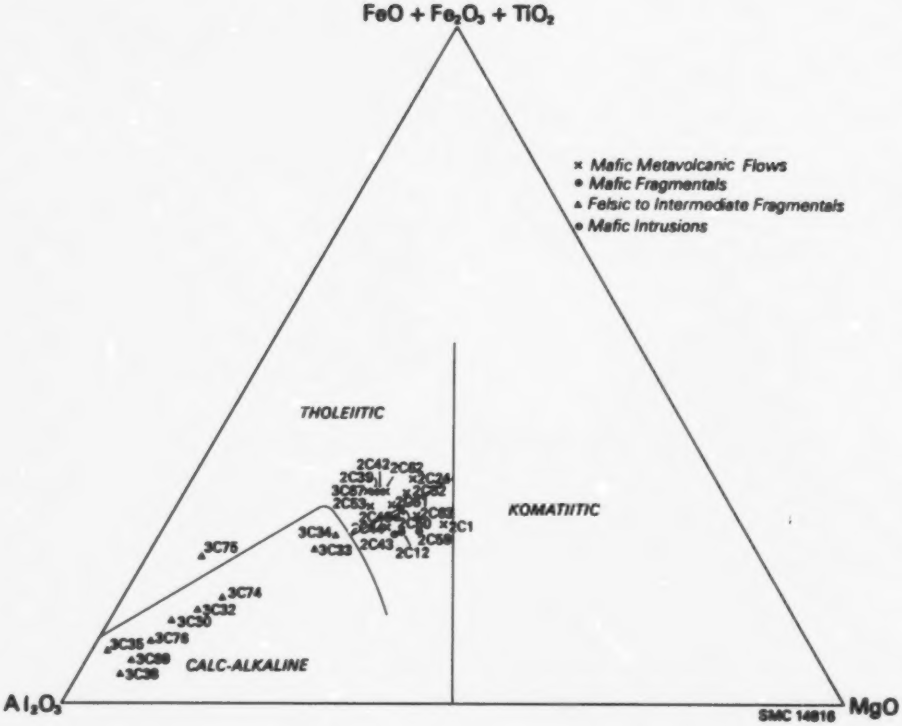

Figure 22–Cation plot, North Sturgeon Lake Assemblage, samples of Begg's 51-75.

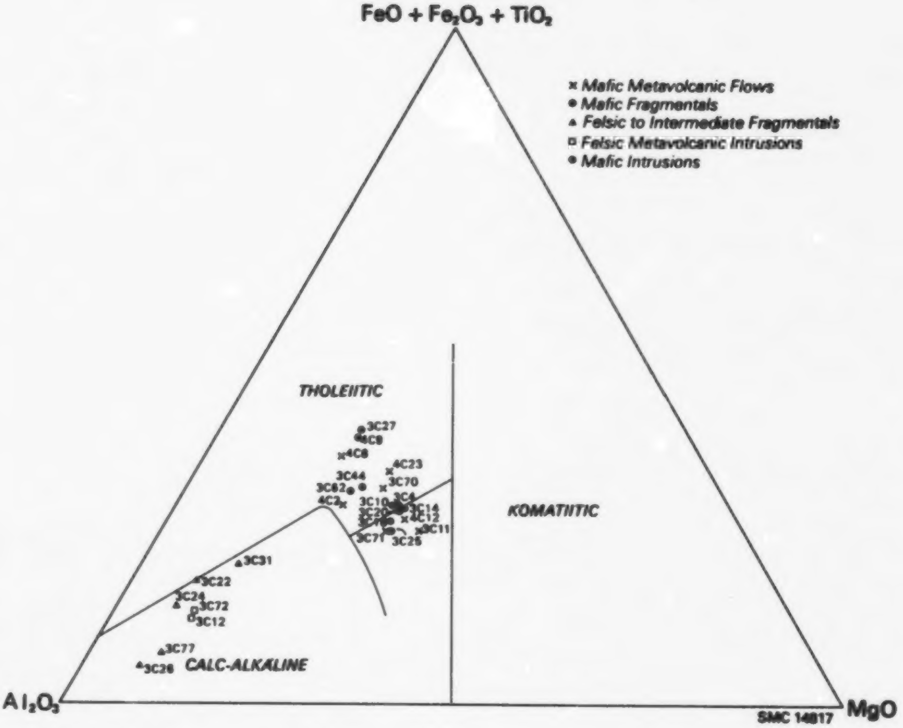

Figure 23–Cation plot, North Sturgeon Lake Assemblage, samples of Begg's 76-99.

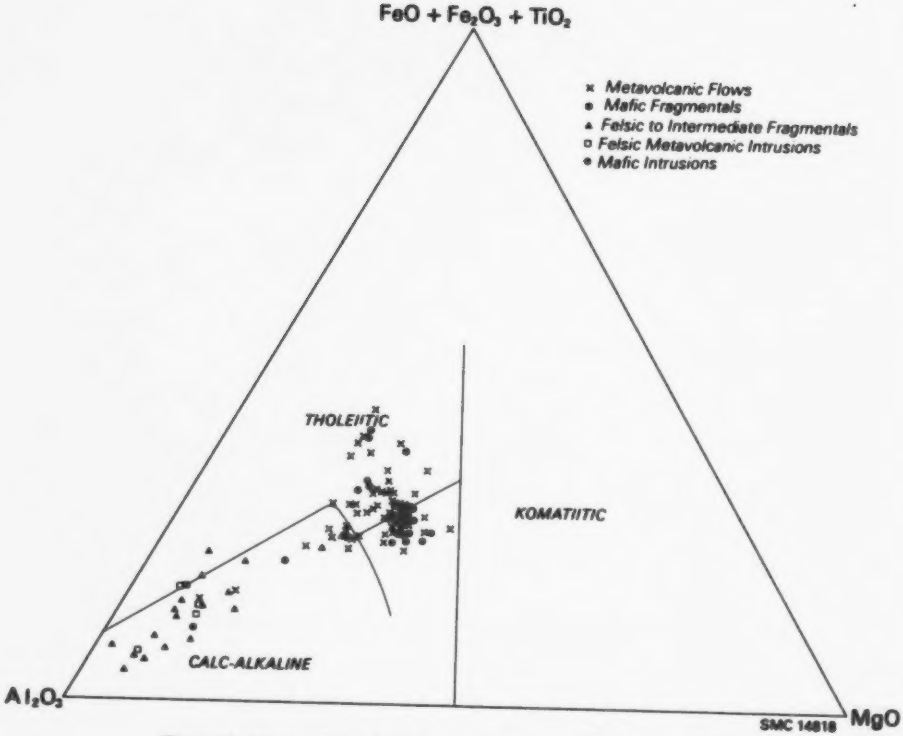

Figure 24–Composite Cation plot, North Sturgeon Lake Assemblage.

NORTHEAST ARM ASSEMBLAGE: MORGAN ISLAND SECTION

The author has subdivided the Northeast Arm Assemblage: Morgan Island Section into five volcanic cycles. From west to east, these are (1) the North Arm Cycle; (2) the Northeast Arm Cycle; and tentatively (3) the Squaw Lake Cycle; (4) the Vista Lake Cycle; and (5) the Vanessa Lake Cycle.

North Arm Cycle

The North Arm Cycle is approximately equivalent to Formations B1 and C1 of the Fourbay Lake Cycle of the North Sturgeon Lake Assemblage; a lower formation of mafic wacke-siltstone is not present. Due to lateral facies changes and inability to trace flow units over any substantial distance, specific units are not necessarily present nor are they correlatable through both cycles.

The North Arm Cycle comprises two formations (Formations A2 and B2).

Formation A2 comprises a lower flow sequence of massive, pillowed, and porphyritic flows. The pillows at the base of Formation A2 are generally large, mattress-shaped, non-amygdaloidal, and have relatively thick selvages. To the north and east, these pillows tend to be smaller and bun-shaped. Porphyritic pillowed flow units are similar to those of Formation B1 of the Fourbay Lake Cycle. These units may define the same stratigraphic level, but separate sources are indicated because the units are not continuous through the two areas.

Formation B2 comprises wacke-siltstone and mafic to intermediate fragmental rocks. The great lateral continuity of the wacke-siltstone unit was interpreted from diamond-drill hole and geophysical information. The wacke-siltstone unit is relatively thin and is graphitic and sulphidic. The fragmental units appear to be laterally equivalent with the wacke-siltstone unit. The fragmental units consist of subaqueously deposited pyroclastic and autoclastic/hyaloclastic material that occupies interflow positions in massive and pillowed flows. These fragmental units are less than 1 m to rarely 30 m thick, are bedded, and contain elliptical clasts that vary in size from 3 to 8 cm. The clasts are heterolithic, and are mafic and intermediate in composition.

Northeast Arm Cycle

The Northeast Arm Cycle comprises three formations (Formation C2, D2, and E2). There is a good correlation between the Jumping Lake-Six Mile Lake (North Sturgeon Lake Assemblage) and Northeast Arm Cycles with respect to the nature of the volcanism. The upper fragmental units of the Six Mile Lake and Northeast Arm Cycles fine to the northeast and to the southwest respectively, such that, at the entrance to the North Arm of Sturgeon Lake, tuffs of both cycles are apparently intercalated. This would suggest that the fragmental units of both cycles are probably coeval and comagmatic, and that they came from separate volcanic centres.

Formation C2 consists of massive, pillowed, and amygdaloidal flows, and minor autoclastic and hyaloclastic breccia material. Thin waterlain mafic tuffs occur near the top of the formation. The pillows are generally bun-shaped and noticeably amygdaloidal with the amygdule size increasing eastwards. Gabbro diorite-intrusions are similar to those described previously in Formation D1 of the Fourbay Lake Cycle.

Similarly to the upper fragmental Formation (Formation E1) of the Jumping Lake - Six Mile Lake Cycle, the fragmental rocks of Formation D2, Northeast Arm Cycle, comprise two main facies: (1) a near-vent pyroclastic/autoclastic facies in the immediate area of Morgan Island bordered by, (2) a subaqueous pyroclastic flow facies.

The near-vent facies is approximately monolithic, is unstratified, and reaches a maximum apparent thickness of 2400 m in the immediate Morgan Island area. It is intermediate to felsic in composition, and is interpreted to represent autoclastic and proximal pyroclastic debris. In general, the coarsest clast size is present in this area.

The subaqueous pyroclastic flow facies northeast of Morgan Island (Trowell 1977) consists of coarse units of massive to locally graded tuff-breccia and volcanic-clast conglomerate. These rocks are heterolithic to monolithic and vary from being clast to matrix-supported. Thinner units of lapilli-tuff and/or pebble conglomerate are graded as are the thinly bedded tuff/wacke beds. Fine ash appears to comprise the background sedimentation. The clast size and bedding thicknesses decrease to the north where distal facies redeposited (and reworked?) pyroclastic material present east of Ouilette Lake. Coarse crystal tuff and lapilli-tuff occur southwest of Morgan Island. In this area, distal facies composed of redeposited volcanic detritus derived from the Jumping Lake-Six Mile Lake and the Northeast Arm Cycles is probably intercalated.

Clasts vary from angular, blocky to subrounded, and elliptical. In decreasing order of abundance, these clasts consist of felsic to intermediate volcanic, intermediate feldspar porphyry, chert, bedded tuff, and vesicular mafic volcanic material. In addition to bedding and graded bedding, local scour structures, fine cross-lamination, and possible flaser structures were observed.

Formation E2 consists of hyaloclastic breccia (Trowell 1974a, 1977; Gordanier 1975); no comparable unit is present in the Jumping Lake - Six Mile Lake Cycle.

Formation E2 (Carbonate Breccia Unit, Trowell 1977) occurs near the top of the Northeast Arm Cycle. The formation contains felsic volcanic clasts and occurs as clasts within the subaqueous pyroclastic flow facies northwest of Morgan Island, and is approximately 4500 m long and up to 200 m wide. The formation attains its maximum thickness in the Morgan Island area. This suggests a near-source (vent) position for it. This unit is stratified to locally graded bedded. Rare crossbedding, scour channels, and soft-sediment deformation were observed. The high degree of vesicularity of this unit suggests that it was formed in relatively shallow water. This unit has the chemistry of an ultramafic rock. The chemical composition of this unit may represent the original composition of this unit or the extensive alteration of an original mafic basaltic composition.

Gabbro-diorite and anorthositic gabbro-diorite sills, dikes, and irregular masses intrude the Northeast Arm Cycle. These are similar to the intrusions that cut the fragmental units (Formation E1) of the Jumping Lake-Six Mile Lake Cycle, but the anorthositic phase is much more abundant here.

Squaw Lake Cycle

The Squaw Lake Cycle comprises two formations (Formations F2 and G2). Formation F2 consists of a mafic volcanic sequence of massive and amygdaloidal flows, pillowed and amygdaloidal pillowed flows, and thin hyaloclastic pillow breccia units. The pillows are generally bun-shaped, small, and coarsely amygdaloidal. The hyaloclastic pillow breccia units are thin and discontinuous. The coarseness of the amygdules and the extensive fragmentation of the hyaloclastic pillow breccia units are indicative of a shallow water environment of formation. The intercalated fragmental units consist of intermediate tuff and lapilli-tuff which merge into volcanogenic wacke-siltstone and pebble conglomerate.

Formation G2 consists of thin discontinuous lenses of intermediate to felsic fragmental units of tuff and lapilli-tuff to lapillistone tuff, and variable wacke and pebble conglomerate. These units are locally bedded. Spherulitic flows/tuffs occur north of Coveney Island. Thin mafic volcanic flows are intercalated with the fragmental rocks. Porphyries and sodic felsite sills and dikes intrude this formation. Gabbro-diorite and anorthositic gabbro-diorite intrusions identical to those of the Northeast Arm Cycle intrude the Squaw Lake Cycle. The anorthositic phases are not as abundant.

Vista Lake Cycle

The Vista Lake Cycle comprises two formations (Formations H2 and I2).

The mafic volcanic sequence (Formation H2) is composed of massive pillowed, and amygdaloidal flows. Thin beds of wacke-siltstone occupy an interflow position. Pillows in the lower part of Formation H2 contain coarse amygdules or gas cavities up to 0.15 m in diameter. The size of amygdules decreases upwards, and probably indicates water depth increased and probably reflects progressive sinking of the volcanic rocks occurred.

Formation I2 is a clastic metasedimentary sequence consisting of thinly bedded wacke-siltstone. It is intercalated with, and in part overlies, Formation H2, this suggests concomitant volcanism and sedimentation. The basal parts of mafic flows that overlie intercalated sedimentary rocks locally contain clasts of the sedimentary rocks.

The wacke-siltstone is locally ferruginous. Graphitic and sulphidic ironstone beds, discontinuous over tens of kilometres, appear at approximately the same stratigraphic level and suggest a rather extensive and stable environment of deposition.

Both formations are intruded by synvolcanic gabbro-diorite masses.

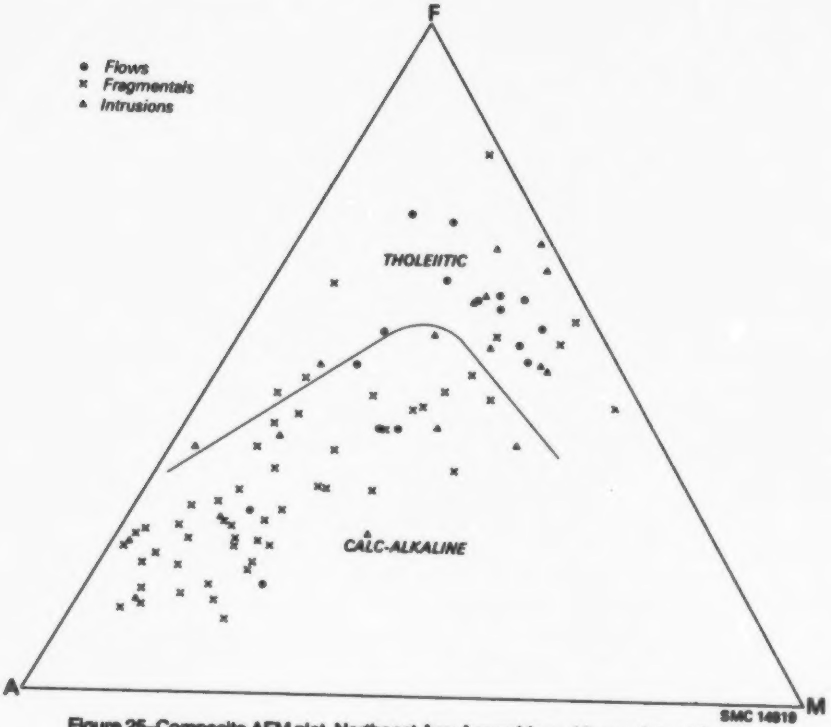

Figure 25–Composite AFM plot, Northeast Arm Assemblage, Morgan Island Section.

Vanessa Lake Cycle

The Vanessa Lake Cycle consists of one Formation (J2) of mafic metavolcanic flows and intercalated wacke-siltstones. It may in fact be the folded equivalent of the Vista Lake Cycle (Formations H2, and I2).

Petrochemistry of the Northeast Arm Assemblage-Morgan Island Section

Chemical data of the Northeast Arm Assemblage, Morgan Island Section (Table 17) are plotted on composite AFM and Cation Plots (Figures 25 and 26).

Sampling of rocks from this section was concentrated on the intermediate to felsic fragmental rocks of the Northwest Arm and Squaw Lake Cycles. This was done in order to compare their chemistry with the chemistry of the South Sturgeon Lake Assemblage. The author has previously expressed (Trowell

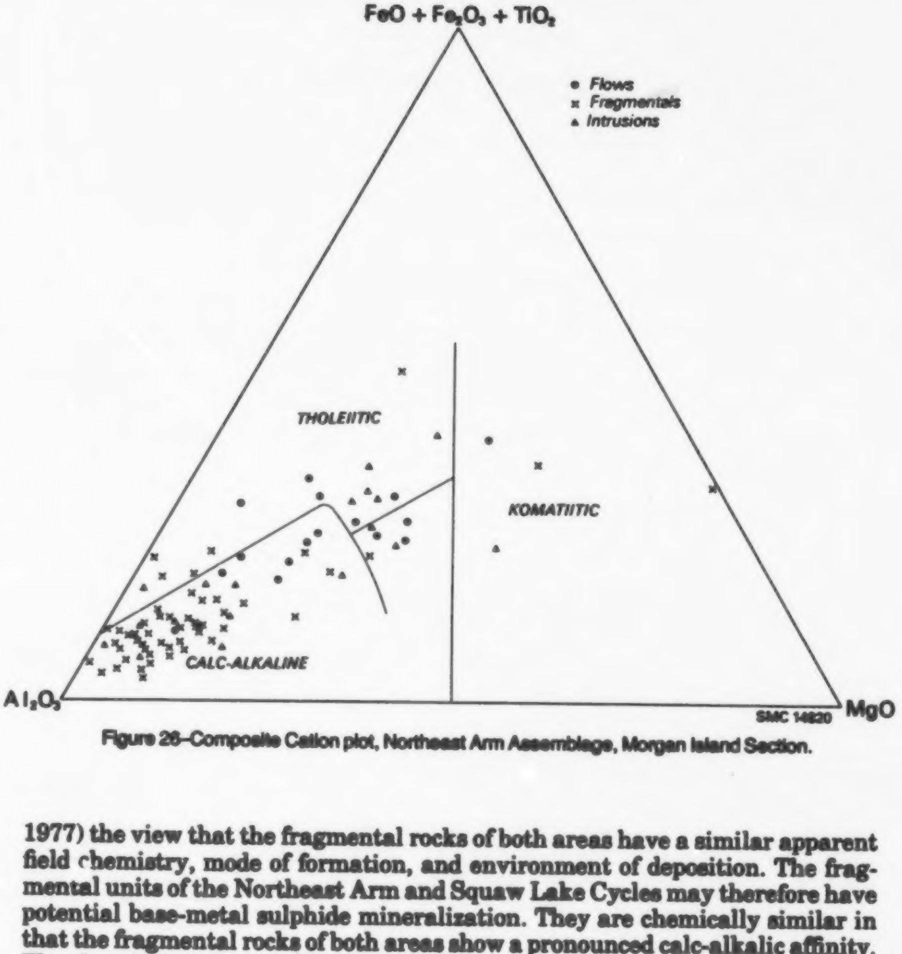

Figure 26–Composite Cation plot, Northeast Arm Assemblage, Morgan Island Section.

1977) the view that the fragmental rocks of both areas have a similar apparent field chemistry, mode of formation, and environment of deposition. The fragmental units of the Northeast Arm and Squaw Lake Cycles may therefore have potential base-metal sulphide mineralization. They are chemically similar in that the fragmental rocks of both areas show a pronounced calc-alkalic affinity. The chemical analyses of fragmental rocks of the Northeast Arm Assemblage do not show the same scatter distribution as do the analyses of the fragmental rocks of the South Sturgeon Lake Assemblage when these have been plotted on AFM and Cation diagrams. These plot in both the calc-alkalic and tholeiitic fields. If the scatter can be attributed to changes in the initial chemistry by alteration processes that accompanied formation and emplacement of the sulphide deposits of the South Sturgeon Lake Assemblage, then the Northeast Arm Assemblage may be a less favourable target for base-metal mineralization.

Mafic flows associated with the fragmental rocks tend to plot in the calc-alkalic field, whereas those comprising lower mafic volcanic formations of the other cycles are dominantly tholeiitic. Mafic intrusions are dominantly tholeiitic, but intermediate to felsic intrusions are calc-alkalic, and are likely to be comagmatic with the fragmental rocks of similar composition.

NORTHEAST ARM ASSEMBLAGE: BECKINGTON LAKE ROAD SECTION

The Northeast Arm Assemblage: Beckington Lake Road Section comprises three volcanic cycles. From west to east, these are the Beckington Lake West Cycle; (2), the Beckington Lake East Cycle; and (3) the Richan Lake Cycle.

Beckington Lake West Cycle

The Beckington Lake West Cycle comprises two formations (Formations A3 and B3). Formation A3 is a lower mafic flow sequence of massive, pillowed, porphyritic, and amygdaloidal flows, with minor interflow intermediate to felsic fragmental units. This sequence is approximately correlative to the North Arm Cycle, Northeast Arm Assemblage: Morgan Island Section.

The porphyritic flows/flow zones contain 5 percent, 1 to 2 cm feldspar phenocrysts. Pillows are generally irregularly shaped, vary from 0.2 by 0.5 to 0.8 by 1.0 m in dimension, and are finely amygdaloidal. A narrow zone of porphyritic pillows may be the lateral equivalent of similar units in the North Shore and Fourbay Lake Cycles.

Intermediate to felsic units occur as dikes/flows and fragmental units occupying an interflow position. The more felsic varieties contain rare felsic lapilli in an intermediate to felsic matrix. Thin mafic bands on the order of less than 1 cm to 5 cm, locally present, could represent the background settling of mafic ash, or in some cases could be metamorphosed calc-silicate layers.

Gabbro-diorite bodies are probably the intrusive equivalents of the mafic flows, but some chemical differences exist between the bodies and flows.

Formation B3 is composed of intermediate and felsic flows (?), hypabyssal intrusive phases, and fragmental rocks. Distinctive porphyritic units are characterized by the presence of up to 3 cm blue quartz eyes; the units are variable, however, and contain quartz and feldspar phenocrysts. Many of the fragmental rocks are in the fine tuff size range. In general, there is a fining trend from the fragmental rocks of the Northeast Arm Cycle northwards to their correlative units within Formation B3. Likewise, some of the fine-grained volcanic detritus could have been supplied from the north by degradation and redeposition of the lower section of the Handy Lake Volcanics in the Savant Lake area (Trowell 1978).

Beckington Lake East Cycle

The Beckington Lake East Cycle comprises two formations (Formations C3 and D3). Formation C3 consists of a lower mafic sequence predominantly composed of massive flows, with minor porphyritic, pillowed, and amygdaloidal flows. A thick wedge characterized by interflow mafic tuffs with wacke lies just west of Beckington Lake, where it is well exposed on the Beckington Lake road. Gabbro-diorites similar to those of the Beckington Lake West Cycle occur predominantly as interflow sills and as more irregular bodies. Thin interflow felsic to intermediate fragmental units are locally present, as well, intermediate volcanic dikes cut the mafic flows.

Formation D3 comprises wacke-siltstone medial to distal turbidites. The evidence for this is based on bed thickness. Semi-continuous bands of sulphidic and graphitic ironstone are present within this formation.

Richan Lake Cycle

The Richan Lake Cycle comprises one formation (E3).

Formation E3 comprises mafic metavolcanic flows with minor interbeds of wacke-siltstone.

Petrochemistry of the Northeast Arm Assemblage-Beckington Lake Road Section

Chemical data for the Northeast Arm Assemblage-Beckington Lake Road Section are presented in Table 18 and Figures 27 to 28 inclusive.

The Beckington West Lake Cycle is composed of a lower sequence of mafic to intermediate flows and an upper sequence of felsic to intermediate fragmental rocks, flows, and hypabyssal intrusive equivalents. The lower sequence is composed dominantly of; tholeiitic basalt flows, two analyses plot within the tholeiitic andesite field; and intrusions, also of tholeiitic affinity that are probably comagmatic to the volcanic rocks. One analysis from a mafic flow that plots in the calc-alkalic field, has been offset toward the Al_2O_3 corner due to the presence of abundant plagioclase phenocrysts. The sample is likely to be of tholeiitic affinity. In contrast to the mafic flows that compose the lower section of the North Sturgeon Lake Assemblage, these mafic flows do appear to plot as two discrete populations with minor scatter; these are, a high-magnesia and high-iron tholeiitic field respectively. These flows are, however, intimately interlayered rather than forming discrete stratigraphic sections.

The upper sequence is composed of calc-alkalic rhyolite, dacite, and andesite with minor basalt. The mafic intrusions that intrude this upper sequence are dominantly gabbro of high-magnesian tholeiitic affinity. One sample of gabbro is quite magnesian and plots in the basaltic komatiitic field. Within this upper fragmental sequence, there does not appear to be any evidence of a simple differentiation trend of the calc-alkalic fragmental rocks from basalt at the base to rhyolite at the top. It could be that these volcanic rocks came from more than one source having been deposited distal to the vent areas. In this case, the chemical data can serve only to identify the rock type, but cannot describe differentiation trends of the stratigraphy.

Metavolcanic flows of the Beckington Lake East Cycle plot as tholeiitic basalts, minor tholeiitic andesites, and one tholeiitic dacite. Calc-alkalic dacite and rhyolite are intrusive into the mafic flows or are tuffs possibly deposited distally from their original source area. The mafic flows plot in the high-

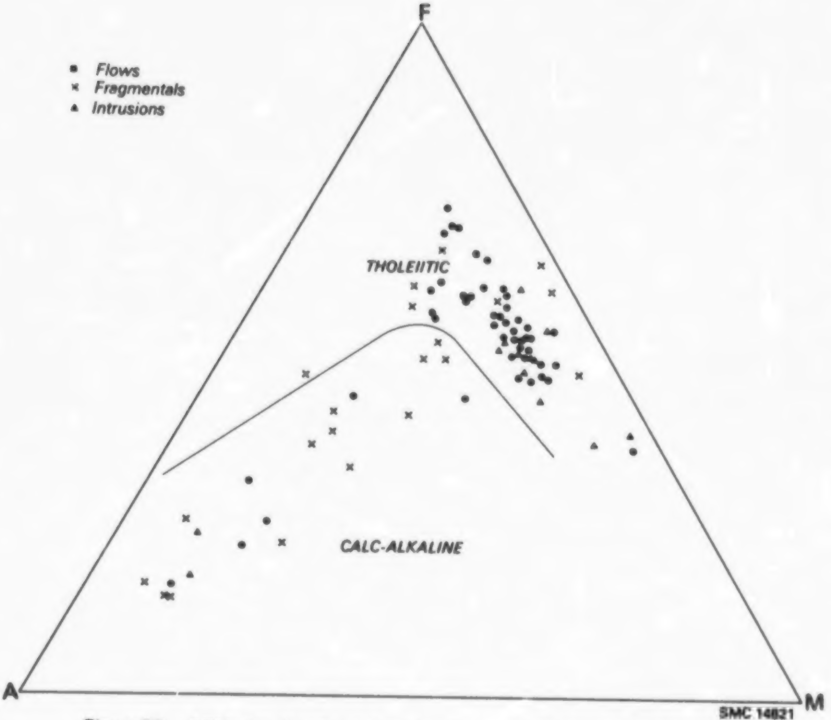

Figure 27 – AFM plot, Northeast Arm Assemblage, Beckington Road Section.

magnesian and high-iron tholeiitic fields. In contrast to the Beckington West Cycle, the flows that plot in these two fields do not appear to define two separate populations, but rather show a scatter about the dividing line between the two fields. The distinction between the two flow types could reflect a lower number of samples for the Beckington West Cycle.

Mafic intrusions again appear to be synvolcanic and comagmatic to the flows. Two samples plot in the basaltic komatiite field (Figure 27). It is uncertain whether these are flows or intrusions.

Only three samples are available from the Richan Lake Cycle. Analyses of these plot in the calc-alkalic dacite and andesite, and high-magnesia tholeiitic fields respectively (Figures 27 and 28). The data is not sufficient to ascribe this cycle to any discrete chemical parentage.

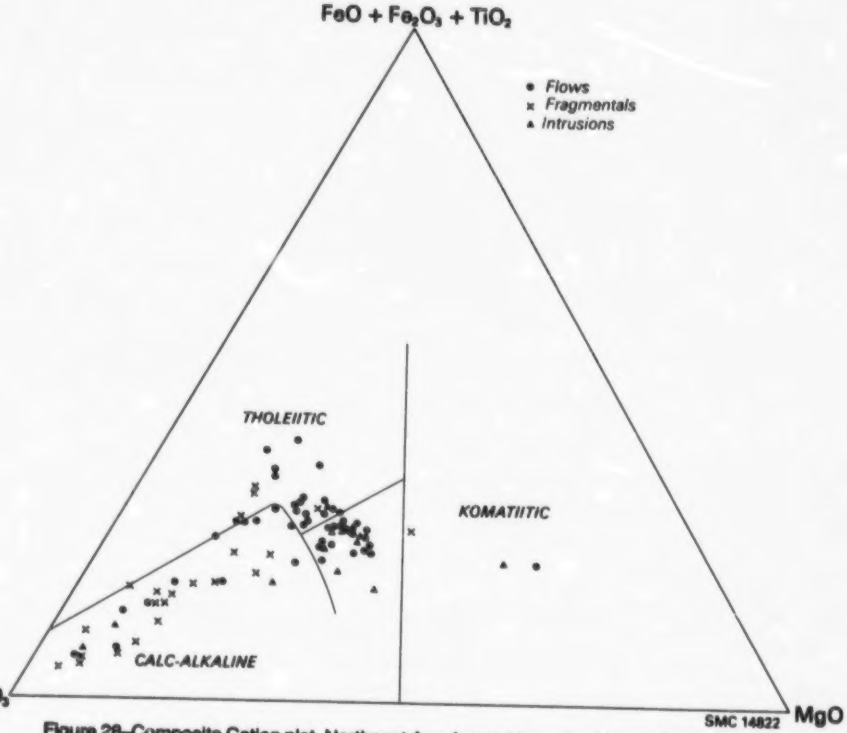

Figure 28–Composite Cation plot, Northeast Arm Assemblage, Beckington Road Section.

STURGEON LAKE ASSEMBLAGE

The author has interpreted the Sturgeon Lake Assemblage to comprise one volcanic cycle, the Central Sturgeon-Post Lake Cycle.

Central Sturgeon-Post Lake Cycle

The Central Sturgeon-Post Lake Cycle comprises three formations (Formations A4, B4, and C4). Formation A4 consists of a lower mafic flow sequence of massive and pillowed, commonly amygdaloidal flows; porphyritic flows; and autoclastic/hyaloclastic breccia zones. Formation A4 disconformably overlies the clastic metasedimentary Formation N (South Shore Cycle, South Sturgeon Lake Assemblage). It also overlies Formation E1, (Jumping Lake-Six Mile Lake Cycle North Sturgeon Lake Assemblage).

West of Highway 599, the metavolcanics (Formation A4) are interpreted from ground magnetic (Barlow 1975c) and gravimetric (Barlow 1975b) data, (due to lack of outcrop) to either; a) overlie the metasediments (Formation N) with marked angular discordance, or else be in fault contact along an extension of the Mountain Island Bay Fault(?) with Formation N.

Basal pillowed flows (Formation A4), situated on the south shore of Mountain Island, contain clasts of metasediments in their basal parts. The clasts appear to have been plastically deformed, and are surrounded by reaction rims indicating the clasts were probably incorporated from Formation N prior to its lithification possibly by fluidization of wet sediments. The pillows are amygdaloidal and have 2 to 5 cm thick selvages. Amygdule size increases to the north, and upwards in the succession which indicates a progressive decrease in relative water depth occurred during the outpouring of the flows. Hyaloclastic pillow breccia outcrops in the basal part of Formation A4, but autoclastic (flow) breccia occurs throughout, being especially abundant at the top of the succession.

The author interprets two volcanic centres to be sources for these mafic flows, one situated north of Post Lake, the other in the vicinity of Mountain Island. The two thickest sections of the Sturgeon Lake Assemblage occur in these locations. In the westward extension of this assemblage, intrusion of the Mountain Island Bay and Granite Bay plutons has further repeated this assemblage. Serpentinized peridotite intrusions (see below) probably emplaced proximal to volcanic centres, are found north of Post Lake and on Mountain Island. In the central part of Sturgeon Lake, the Sturgeon Lake Assemblage is represented by only a thin veneer of mafic flows and rare intermediate to felsic fragmental rocks.

Formation B4 comprises, intermediate pyroclastic and autoclastic breccia, redeposited fragmental materials, and locally ferruginous wacke-siltstone that overlies Formation A4. The upper flows of Formation A4 are of the high-magnesia tholeiitic variety in contrast to the high-iron tholeiitic flows that comprise the lower sequence. Ultramafic intrusions also occur at this level just below Formation B4, but the relative ages of these units are not known. North of Post Lake, these fragmental rocks (Formation B4) are enveloped by mafic flows of Formation A4.

Overlying the lower volcanic formations (Formations A4 and B4) are the two clastic metasedimentary sequences (Formation C4): (1) the Quest Lake-Princess Lake metasediments; and (2) the East Bay-Sturgeon Narrows metasediments. The author has interpreted the Quest Lake-Princess Lake conglomerate and wacke to be deposited by a debris flow mechanism, whereas the East Bay metasediments were possibly deposited by fluvial processes or as a possible proximal turbidite facies. In both areas it would appear that these two clastic metasedimentary sequences overlie sandstones and shales with apparent conformity. These sandstones and shales are the more distal equivalents of the upper clastic metasedimentary sequence (Formation N) of the South Sturgeon Lake Assemblage.

Arkosic wacke, variable to pebbly arkosic wacke, and arkosic conglomerate facies comprise the East Bay metasediments. They exhibit the following sedimentary features: grading (normal), scour and fill, large-scale crossbedding (1 cm to 1 m thick beds, also graded), shale ripups, rare ripples, soft-sediment deformation structures, and clast imbrication.

Very thick (to 2 m) arkosic wacke beds and thinner beds of graded shaly siltstone are interbedded with the conglomerate. The conglomerate, pebbly arkosic wacke, and arkosic wacke beds have planar tops and bottoms and show local disrupted graded bedding.

The conglomerate is generally matrix-supported though clast-supported zones with upwards of 75 percent clasts have been recorded. Clasts are generally subangular to slightly subrounded, and consist of in decreasing order, felsic metavolcanics, felsic welded tuff, felsic tuff with fiamme, mafic volcanic rocks, shaly siltstone, and some rare intermediate feldspar porphyry volcanic clasts. Blocks of intermediate tuff breccia up to 3.5 by 2.5 m are present in one locality. The shaly siltstone has in places been scoured by the conglomerate and pebbly arkose. This fact plus the presence of extremely large clasts possibly indicates the volcanic detritus was deposited upon a steep paleoslope.

Up to 2.5 cm blue quartz grains characterize the arkosic wacke and conglomerate of the immediate East Bay Area. Similar quartz crystals occur in the trondhjemite body situated northwest of East Bay. This intrusion could have formed and been emplaced contemporaneously with the volcanism, and thus could have been available to provide detritus to the sediments of East Bay.

Wacke and siltstone found near the south end of Sturgeon Narrows are interpreted to be the distal equivalents of the coarse clastics of East Bay. Crossbedding indicates these rocks face northwest opposing the east-facing mafic volcanics that comprise the upper sequence of the North Sturgeon Lake Assemblage. In East Bay, they face predominantly north, but reversals were noted.

A gabbro-clast conglomerate outcrops on and to the west of Princess Lake. It overlies, possibly with a slight angular discordance, both the Central Sturgeon Lake Assemblage and wacke-siltstones that are the distal equivalents of the coarser clastic units of Formation N, South Sturgeon Lake Assemblage.

The conglomerate is composed of major gabbro and mafic volcanic clasts and minor intermediate volcanic clasts set in a lithwacke matrix. The matrix consists of about: 70 percent fine mafic clasts; 10 percent subangular zoned plagioclase crystals, crystal fragments and minor quartz crystals; and 10 percent interstitial fine-grained quartz, feldspar, and chlorite. It is unsorted, not bedded, and grading was not observed. The rock was most likely deposited by a debris flow mechanism that was either subaerial or subaqueous. To the northeast this unit shows a facies change to pebbly wacke and siltstone where eventually it pinches out. It is interpreted as possibly being the time-stratigraphic equivalent of the East Bay metasediments.

Four bodies, possibly sills, of serpentinized peridotite intrude the Sturgeon Lake Assemblage north of Post and Barge Lakes, along a strike extent of approximately 6 km. They vary from approximately 0.8 to 2.4 km in length and 200 to 500 m in width. Their long dimensions trend east-southeast and are approximately parallel to the foliation of the metavolcanics. Ultramafic dikes on Mountain Island are coeval and comagmatic with these intrusions.

These bodies are situated between the lower mafic volcanic flows sequence and the upper intermediate fragmental sequence of the Central Sturgeon-Post Lake Cycle. These bodies were previously described by the author (Trowell 1976) and more recently by R.V. Zalnierinunas (1978).

The intrusions are composed of serpentinized peridotite (originally wehrlite and dunite) with a capping of magnesian gabbro. The dikes on Mountain Island consist of a central peridotitic core bounded by marginal magnesian gabbro borders.

The serpentinized peridotites consist of 50 to 90 percent serpentinized olivine pseudomorphs, 0 to 30 percent remnant olivine, 0 to 15 percent remnant augite, 5 to 15 percent tremolitic amphibole, 0 to 5 percent carbonate, 5 to 10 percent magnetite, 1 to 2 percent chromite, 1 to 2 percent sulphide minerals, and 0 to 5 percent chlorite (Trowell 1976; Zalnierinunas 1978).

Accesories include biotite, talc, epidote, deweylite, and clay minerals. The augite is also locally serpentinized. Serpentine minerals include antigorite, chrysotile, and lizardite (Zalnierinunas 1978).

The gabbros consist of 5 to 15 percent augite, 15 to 30 percent tremolite-actinolite, 20 to 35 percent plagioclase, 0 to 3 percent biotite, 1 to 3 percent opaques and less than 1 percent orthopyroxene. Alteration minerals include chlorite, carbonate, serpentine, talc, quartz, hematite, and epidote (Zalnierinunas 1978).

The gabbros are medium to coarse grained with a subophitic to allotriomorphic-granular texture. Augite, tremolite-actinolite and plagioclase all occur as phenocrysts. The gabbros vary from being massive to well foliated.

The serpentinized peridotites are variably fractured, and sheared, to weakly foliated. Shearing increases in intensity toward the contact with the volcanic rocks. This contact has not been observed, but is believed to be originally intrusive and was modified by later shearing. The peridotites are generally highly magnetic. These rocks are crisscrossed by serpentine, magnetite, and talc veinlets. With the exception of a local banded structure defined by alternations in the grain size of olivine, internal zoning or layering was not observed. The volcanic rocks bordering these intrusions have been variably altered and largely chloritized but are also carbonatized and silicified. One to three percent sulphide minerals, namely pyrite and pyrrhotite are locally present in the volcanic rocks marginal to these bodies.

These bodies are generally approximately lensoid or sill-like in shape or form dikes on Mountain Island. No flow features were observed by the field party.

Samples from these bodies were analyzed for major and minor oxides and selected trace elements (*see* Table 24).

Analyses of the gabbros that intrude the mafic volcanics plot into two distinctive suites on the Cation Plot (Jensen 1976). These are; high-magnesian tholeiite to basaltic komatiite for those rocks that roof the ultramafic rocks and high-iron tholeiite for those rocks not spatially associated with the ultramafics. On the same plot, the ultramafic rocks plot in the ultramafic komatiitic field (*see* Figure 32).

The author would prefer not to use the term komatiite for these bodies because there is neither any evidence for extrusive equivalents nor are all their chemical parameters consistent with those of the komatiites.

On an Al_2O_3-CaO-MgO Plot, (*see* Figure 31) the ultramafics plot close to the MgO end, averaging better than 80 percent relative MgO, and thus fall into the field of high-magnesian ultramafic rocks that can have associated nickel sulphide bodies (Naldrett and Cabri 1976). Nickel sulphide minerals are reported to be present in one diamond-drill hole north of Barge Lake (Palonen *et al.* 1976).

Trace element data (Table 24) are generally consistent for ultramafic rock values. These bodies would, however, appear to contain anomalously high values of Sn and Pb. One sample (4-299-23a) *not in Table 24* contains 1180 ppm Pb and 200 ppm Sn. No explanation of these values is readily available. Several samples of the ultramafic bodies were analyzed for platinoid group elements, but only trace palladium and rhodium were detected *and are not listed in Table 24*. Zalnierinunas (1978, p.29), summarized his views on the petrogenesis of these bodies:

> Originally these rocks formed as olivine cumulates, which olivine fractionation and differentiation model explains why the related gabbros formed and why nickel and cobalt values tend to be higher for early formed cumulates while later formed olivine cumulates tend to have higher copper, lead, zinc, and chromium values. This may also explain why disseminated sulphide minerals tend to be locally found near the contacts of these bodies.
>
> Variations in these six trace elements for Body D indicate that there may have been four or five minor disturbances, surges or influxes of fresh material while the peridotite was forming.
>
> Mole ratio diagrams indicate that the dykes on Mountain Island and the four intrusive bodies evolved from a parent which had the same initial bulk composition indicating that all of these rocks formed from the same parental magma.

The author considers these bodies to have been emplaced in the two vent areas (already mentioned) of the Central Sturgeon-Post Lake Cycle at a period which was probably post-volcanism, but was syntectonic to subsequent metamorphism and orogenic activity.

Petrochemistry of the Sturgeon Lake Assemblage

The metavolcanic units of the Post Lake-Mountain Island Cycle (Sturgeon Lake Assemblage) are predominantly composed of tholeiitic basaltic flows (Tables 19 to 23 inclusive, Figures 29 to 30 inclusive) of high-iron affinity. Minor high-magnesian flows are found scattered throughout the high-iron flows as well as occurring at the same stratigraphic level as the ultramafic intrusions on Mountain Island. Calc-alkalic basalt and andesite flows occur near the top of this cycle on Mountain Island, west along Highway 599, and in the Post Lake area. Calc-alkalic dacite fragmental rocks are found north of Post Lake and on the islands in the central part of Sturgeon Lake. The fragmental units on the islands may be distal units of either the Mountain Island or Post Lake sequences. Where these fragmental units are exposed the lower tholeiitic sequence is represented by only a thin veneer of flows possibly reflecting an original topographic obstruction between the two surmised vent areas (Post Lake and Mountain Island areas respectively) postulated above.

Mafic intrusions in this cycle fall into two discrete groupings:

(1) High-magnesia tholeiitic intrusions that formed as differentiates of the ultramafic intrusions as previously discussed,

(2) High-iron tholeiitic intrusions that are likely synvolcanic and comagmatic to the flows.

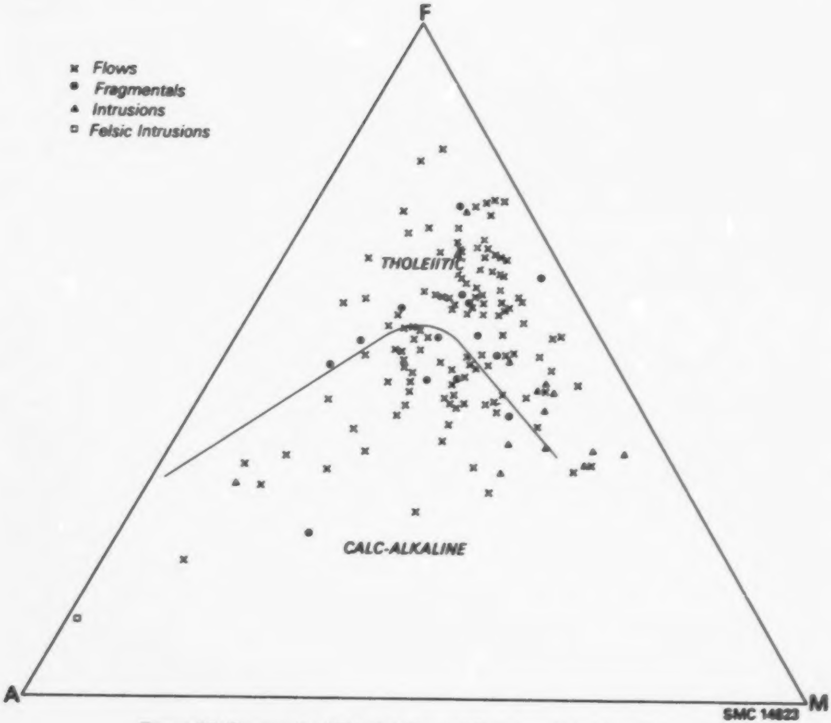

Figure 29–Composite AFM plot, Central Sturgeon Lake Assemblage.

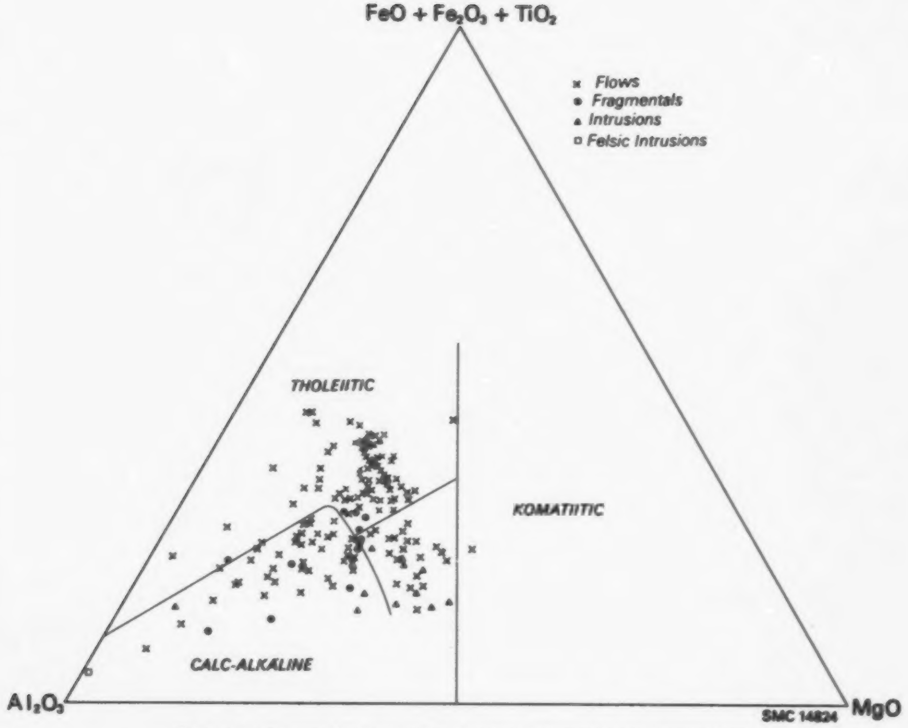

Figure 30–Composite Cation plot, Central Sturgeon Lake Assemblage.

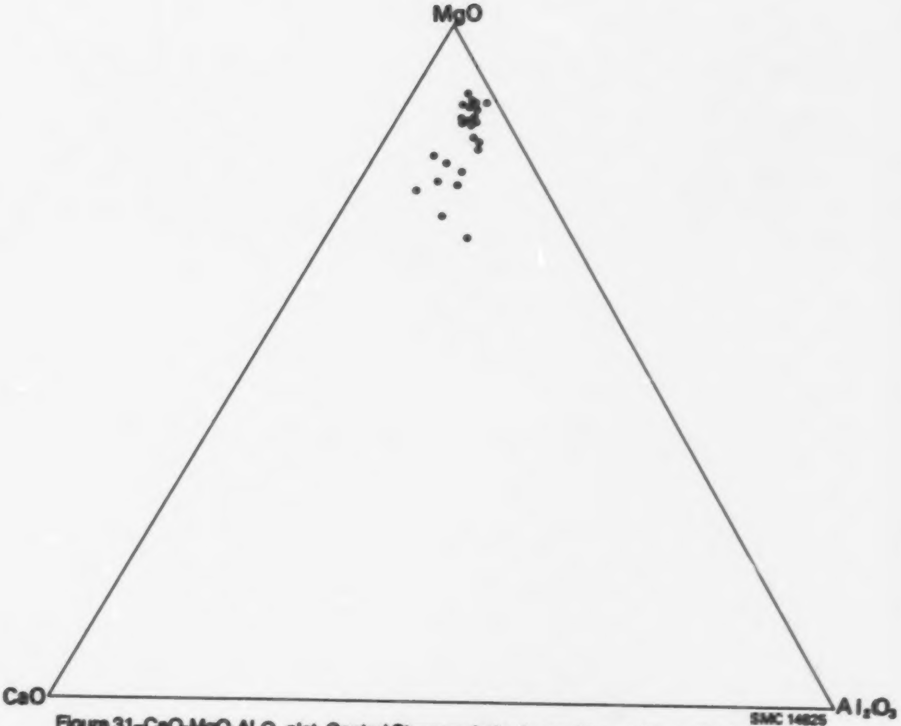

Figure 31–CaO-MgO-Al_2O_3 plot, Central Sturgeon Lake Assemblage - Ultramafic Intrusions.

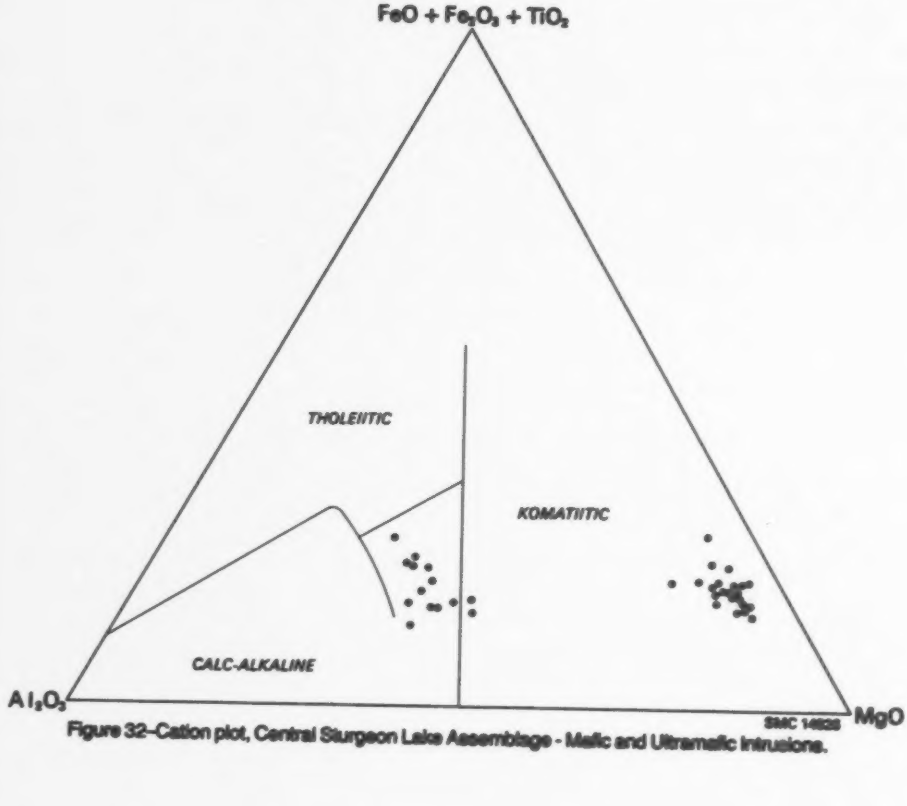

Figure 32–Cation plot, Central Sturgeon Lake Assemblage - Mafic and Ultramafic Intrusions.

STRUCTURAL GEOLOGY

Folding

Two major synclinal structures dominate the map-area (*see* Figure 2, Chart A, back pocket).

The South and North Sturgeon Lake Assemblages approximately form the opposing limbs of a synclinal structure. The axial trace of this structure extends from west of Mountain Island, along the north side of Sturgeon Lake, and eastwards through the Princess-Quest Lakes area. In the western part of the area, the axial trace has been deflected around and has been bifurcated into subsidiary anticlinal and synclinal structures by the emplacement of the Mountain Island Bay and Granite Bay Plutons.

A second synclinal structure trends approximately northwest from north of Post Lake to Sturgeon Narrows where it swings to the northeast through to Vanessa Lake, and possibly continues north through the area east of Beckington Lake. This structure has been interpreted to exist on the basis of very few top determinations, so that its exact trend and placement is somewhat speculative.

Even though a cross-folding pattern is apparent, the author would suggest that there was a continuum of deformation. This continuum began initially with downwarping of the volcano-sedimentary belt due to gravitational instability. This was accompanied by a concomitant rise of granitoid material and ended with the emplacement of the late to post-tectonic granitoid plutons.

Anticlinal structures appear to be broad, widely-spaced, probably steeply plunging structures accounting for minor modifications of the strike trends.

Top reversals in the metasediments in East Bay and the Quest Lake-Princess Lake-Vista Lake area are indicative of internal, possibly tight isoclinal folding. These folds were probably developed subsidiary to the main fold structures.

The author has interpreted the Vista Lake Complex to have been emplaced along a synclinal structure. The complex was probably emplaced along a downwarp in the volcano-sedimentary belt due to a thrusting mechanism.

Top reversals occur in the northern part of the area, specifically along the Northeast Arm of Sturgeon Lake, but have not been recorded or do not occur enough to adequately delineate traces of fold structures.

Faults

Numerous faults and lineaments transect the map-area.

Pervasive shearing associated with movement along the Sturgeon Narrows Cataclastic Zone extends from the top of the Northeast Arm of Sturgeon Lake southeast through Sturgeon Narrows. Late movement along this zone is indicated by brecciation of the Sturgeon Narrows Alkalic Complex and the development of kink folds in intermediate to felsic schists and phyllites along the

Northeast Arm. The development of similar kink folds in intermediate to felsic schists along the south shore of Sturgeon Lake suggests that this structural zone probably extends to the west end of Sturgeon Lake. The angular discordance between the clastic metasediments and underlying metavolcanics of the South Sturgeon Lake Assemblage may be caused by faulting rather than being an unconformity. Cataclastic textures, as seen in thin sections of intermediate to felsic fragmental rocks situated between the top of the Northeast Arm and the northern margin of the map-area, may indicate northwards continuity of this structural zone. It is perhaps feasible that it eventually joins the Savant Lake Fault, a similarly trending structure found on Savant, Harold, and Harris Lakes (Bond 1976; Trowell 1978).

In the Northeast Arm area, shear zones too numerous to show on the accompanying maps reflect movement along this zone. Tight shear folding developed coplanar to the schistosity could explain local, rapid reversals in facing directions. The shear zones trend both parallel and discordant to primary bedding.

The Mountain Island Bay Fault is indicated both by shear and carbonatized zones in mafic metavolcanics and by ground magnetic data (Barlow 1974a, 1974b).

The other faults, lineaments/faults, and shear zones in the report-area are zones of brittle fracture arrayed in a pattern consistent with the postulated folding of the volcano-sedimentary belt. Faults and shear zones parallel to stratigraphy may in some cases be early (thrust) planar structures rotated into their present position. Possible late reactivation occurred along them.

ECONOMIC GEOLOGY

Copper, zinc, silver, lead, gold, molybdenum, iron, fluorite, and uranium mineralization have been reported from the map-area. Gold and silver production from the area began in 1901 (*see* St. Anthony Mine, Table 1). Copper, zinc, silver, and lead are presently being mined from the Mattabi and Lyon Lake orebodies (*see* Table 1).

The various types of mineralization types are discussed below. Reference is made to individual deposits to show type examples of the mineralization discussed.

Base-Metal Massive Sulphide Deposits

COPPER, ZINC, SILVER, LEAD

Table 1 lists the base-metal massive sulphide deposits of the Sturgeon Lake area. All deposits found as yet are situated within the South Sturgeon Lake Assemblage. These deposits occur near the top of the Darkwater and Lyon Lake Cycles, but as noted previously, Franklin (1977) and Franklin and Gibb *et al.*

(1977) consider these deposits to have formed during one volcanic cycle. Lavin (1976) in his study of mineralized cycles in the Sturgeon Lake area, and V.J. Sopuck (1977) and McConnell (1976) in their references to the area, use Franklin's 1975 (*see* Table 11) stratigraphy as does Hinzer (1977) in his study of the Lyon Lake ore zone.

The author does not know how the statistical parameters the above-mentioned authors used to evaluate mineralized versus unmineralized cycles would change if they had used Franklin *et al.'s* (1977) stratigraphy (*see* Table 11).

Franklin (1977), Franklin *et al.* (1976, 1977), and J.C. Hinzer (1977) have described the Mattabi Mines Limited and Sturgeon Lake Mines Limited orebodies respectively. The reader is referred to the works of these authors for detailson the setting of these orebodies.

O.P. Lavin (1976) studied the South Sturgeon Lake Assemblage to determine whether mineralized and unmineralized cycles could be distinguished by applying statistical analyses to whole rock and trace element chemical data. Lavin used various statistical methods, including regression and discriminant analysis. His conclusions are: a) mineralized cycles in the Sturgeon Lake area have a unique chemistry, that is different from the unmineralized cycles; and b) this unique chemistry is due to widespread alteration processes, but the presence of primary differences in the magma, or source area for the magma if derivedby partial melting, cannot be ignored.

Lavin (1976) treated all rock units the same irrespective of the chemical suite to which they belong. The author suggests that if it were possible to classify the rock units into their respective magmatic suites, statistical analysis (following the approach of Lavin 1976) on a suite basis might allow for a refinement in discriminating between unmineralized and mineralized cycles. It might be possible to separate out the effects of alteration from those effects, if any, due to primary magmatic differences. Similarly, application of the discriminant functions determined for the South Sturgeon Assemblage to other volcanic sequences that may be lithologically and time-stratigraphic equivalents to it, as for example, the Handy Lake Volcanics in the Savant Lake area (Trowell 1978), could be a useful exploration tool.

Several authors, such as C. Brooks and L. Gelinas (1977) have commented upon the observation that base-metal massive sulphide deposits of the Canadian Shield appear to be predominantly associated with calc-alkalic volcanism. At Sturgeon Lake, however, the association is with mixed tholeiitic and calc-alkalic metavolcanics. A.F. De-Rosen Spence (1976) has also noted that some of the massive sulphide deposits of the Noranda area are also hosted by tholeiitic metavolcanics. P.J. MacGeehan (1978) made the observation that the calc-alkalic trends may be pseudo-trends, in that they develop due to alteration during the development of a sea-floor hydrothermal system. These observations allow a much broader scope for mineral exploration for base-metal massive sulphide deposits, but also, as Lavin (1976) has pointed out, they mean that more attention should be paid to subtle but pervasive alteration modifications reflected in the major rock chemistry.

Gold

Gold occurrences within the map-area can be classed into three types:

(1) Those related to volcanic and subvolcanic stratigraphy,

(2) Those associated with later felsic intrusions that intrude volcanic stratigraphy,

(3) Those within quartz veins not directly related to volcanic stratigraphy or specific intrusions.

An example of the first type would be the gold mineralization of the Darkwater Mine (Trowell 1974a) that is found in the subvolcanic Beidelman Bay Pluton. Gold (and silver) mineralization at the St. Anthony Mine (Table 1, Trowell 1977) is associated with a later granodiorite pluton that has intruded mafic metavolcanics, (Trowell 1977) and is an example of type two gold occurrences. Examples of the third type include several gold-bearing quartz + carbonate veins found along the Northeast Arm of Sturgeon Lake (Trowell 1977).

Molybdenum

Visible molybdenite occurs in the Beidelman Bay and Shanty Lake (Trowell 1970, 1974) subvolcanic plutons and in metasediments (one occurrence) on Quest Lake (Trowell 1976). Only trace amounts, however, are present in samples submitted for assay.

The molybdenum in the subvolcanic intrusions is associated with porphyry copper-type occurrences within these plutons (Trowell 1974; Friske 1974; Franklin *et al.* 1977). The occurrence on Vista Lake is of unknown origin.

The low values of molybdenum present suggest there is little economic potential for these occurrences.

Iron

Ironstone units within the area are rarely exposed. Their size and lateral extent have been interpreted from aeromagnetic Ontario Department of Mines-Geological Survey of Canada (1961a,b,c and d) and ground magnetic (Barlow 1974a, 1975a) data, and diamond drilling (Assessment Files Research Office, Ontario Geological Survey, Toronto).

Two types of ironstone are present within the area: (1) sulphidic ironstone interbedded with graphitic mudstone intercalated within the volcanic sequences, and (2) quartz-magnetite ironstone interbedded with chert or siliceous mudstone within clastic metasedimentary sequences. Both varieties could have originated from volcanic sources as suggested by Shegelski (1978).

Interbedded quartz-magnetite ironstone and chert occurs within the upper clastic metasedimentary sequence (Formation N) of the South Sturgeon Lake Assemblage. East of the map-area, a detailed evaluation of this unit was done by C.H. Hopper (Assessment Files Research Office, File 63-907, Ontario Geological Survey, Toronto). Within the map-area geophysical modelling, based on ground magnetic data, Barlow (1975a, b, and c) indicated that this unit contains significant iron mineralization, but it is probably buried too deeply to be of current interest.

Fluorite

Fluorite mineralization is ubiquitous in the Sturgeon Narrows Alkalic Complex. It occurs as disseminated grains and is variable from trace to 1 percent in abundance. Local disseminations up to 2 percent and joint fillings of pure fluorite were noted: (1) in a sheared carbonatized zone on the middle island of Sturgeon Narrows (Trowell 1976); (2) in diamond-drill core from the former W.G. Wahl Limited property (Trowell 1976); and (3) as 1 to 2 percent disseminations and joint fillings on the south shore of East Bay (Trowell 1977). A sizeable amount of fluorite is present in this complex as disseminations throughout all phases, but no concentrated zones having economic potential have been detected.

Radioactive Mineralization

Along Sturgeon Narrows, showings having high radioactive responses contain low but measurable amounts of U_3O_8 equivalent (Rodgers 1964). These showings occur in breccia and shear zones within both the Sturgeon Narrows Alkalic Complex and bordering fenitized host rocks. Post-emplacement movement along the Sturgeon Narrows Cataclastic Zone probably resulted in local concentrations of original U_3O_8 equivalent mineralization present within the alkalic complex. These showings are spot anomalies and show no lateral continuity. Neither do the airborne surveys (Ontario Department of Mines-Geological Survey of Canada 1976a) show any areas of anomalous radiation over the alkalic intrusive complexes in the map-area. Economic potential is probably minimal. An expanded discussion of potential radioactive mineralization within the map-area is contained in Trowell (1977). New Santiago Mines Limited (Mineral Resources Circular Number 9, Robertson 1968) reported uranium mineralization on Seaton and Coveney Islands and at Anderson Lake. These were not found, and thus not confirmed, by the author.

Considerations in Future Exploration

GOLD (SILVER)

Re-examination of the environs of gold mineralization at the St. Anthony Mine (Trowell 1977) is warranted. Specific attention should be paid to any carbonatized mafic metavolcanic flows along strike from those intruded by the St. Anthony Pluton. Other locations where massive granodiorite-trondhjemite discordantly intrude the volcanic stratigraphy, are the North Arm Pluton and associated dikes (King Bay Gold Occurrence; Trowell 1977) and the Chilveston Lake area east of the town of Savant Lake.

The Darkwater Mine (Horwood 1937b; Trowell 1974) is situated within the Beidelman Bay Pluton. Even though no production occurred at this mine, a re-examination of the area may be warranted in the light of a possible "porphyry" gold association. Similarly, the Shanty Lake Pluton could be examined.

A carbonate breccia unit (Trowell 1977), with associated chert (Gordanier 1975), contains slightly anomalous gold contents. Quartz veins that cut the breccia give assays appreciably high in gold and copper. A grab sample of a 2 cm wide quartz vein and host carbonate breccia assayed 8.70 ounces of Au per ton, and 4.26 percent Cu. This association of carbonatized (primary) hyaloclastites of possible ultramafic composition containing anomalous gold, chromium, nickel, titanium, and manganese values is part of a favourable stratigraphy for potential gold mineralization. Specific attention should be paid to locating structural dislocations or quartz veins or stockworks within this unit where possible upgrading of initial gold values could have occurred.

Measurable gold occurs in the base-metal massive sulphide minerals of the area (Table 1). Examination of the host rocks of these deposits might be warranted.

COPPER, ZINC, SILVER, LEAD (BASE METALS)

The South Sturgeon Lake Assemblage is still a likely prospecting target, as further discoveries may be made at depth. The author considers that the Northeast Arm Assemblage-Morgan Island Section warrants exploration due to the abundance of intermediate to felsic fragmental rocks of calc-alkalic affinity.

COPPER, MOLYBDENUM

The copper and molybdenum occurrences in both the Beidelman Bay and Shanty Lake Plutons have been examined. Not all of these bodies have been systematically examined, however, and the possibility of low-grade "porphyry" copper and molybdenum mineralization being discovered still exists.

REFERENCES[1]

Ayres, L.D.

1972: Guide to Granitic Rock Nomenclature Used in Reports of the Ontario Division of Mines; Ontario Division of Mines, Miscellaneous Paper 52, 14p.

1974: Geology of the Trout Lakes Area, District of Kenora (Patricia Portion); Ontario Division of Mines, Geological Report 113, 197p. Accompanied by Map 2270, scale 1:31 680.

1977: Importance of Stratigraphy in Early Precambrian Volcanic Terranes: Cyclic Volcanism at Setting Net Lake, Northwestern Ontario; p.243-264 *in* Volcanic Regimes in Canada, Edited by W.R.A. Baragar, L.C. Coleman, and J.M. Hall, Geological Association of Canada, Special Paper 16, 476p.

Barker, D.S.

1974: Alkalic Rocks of North America; p.160-172 *in* The Alkaline Rocks, Edited by H. Sorenson, John Wiley and Sons Incorporated, New York, 622p.

Barlow, R.B.

1974a: Ground Vertical Field Magnetics, Sturgeon Lake, Ouilette Lake-Coveney Island Sheet, District of Thunder Bay (52 J/2); Ontario Division of Mines, Map P.958, Geophysical Series, scale 1:15 840.

1974b: A Magnetic Survey of the Northern Part of Sturgeon Lake Area (East Part), District of Thunder Bay; p.169-173 *in* Summary of Field Work 1974, by the Geological Branch, Edited by V.G. Milne, D.F. Hewitt, and K.D. Card, Miscellaneous Paper 59, 206p.

1975a: Ground Vertical Field Magnetics of the Sturgeon Lake Area, Squaw-Vista-Vanessa Lakes Sheet, District of Thunder Bay (52 J/1W, 2E); Ontario Division of Mines, Map P.1051, Geophysical Series, scale 1:15 840.

1975b: Bouguer Gravity Map of the Sturgeon Lake Area, District of Thunder Bay and Kenora 52 G/14, 15, 16W; 52 J/1,2,3); Ontario Division of Mines Preliminary Map P.1050, Geophysical Series, Survey and Compilation by R.B. Barlow, D.R. Wadge, and T.H. Dusanowskyj 1974, scale 1:63 360.

1975c: Magnetic Investigation of the Southern Part of Sturgeon Lake, Districts of Kenora and Thunder Bay; Ontario Division of Mines, Open File Report 5151, 66p. Accompanied by Map P.922, and Map P.923, scale 1:15 840.

Beggs, D.G.

1975: Petrology and Geochemistry of Archean Volcanic Rocks North of Sturgeon Lake; Unpublished M.Sc. Thesis, University of Toronto.

Bond, W.D.

1976: Geology of Conant, Jutten, and Smye Townships (Savant Lake Area), District of Thunder Bay; Ontario Division of Mines, Open File Report 5213, 186p. Accompanied by Maps P.803, P.804, and P.805, scale 1:15 840.

Brooks, C., and Gélinas, L.

1977: The Relationship of Base Metal Mineralization to Chemostratigraphic Divisions in Volcanic Rocks of Canadian Archean Greenstone Belts; Research Paper 77-1, Mineral Exploration Research Institute, Montreal.

Chou, C.L.

1977: Trace Element Geochemistry of Archean Volcanic Rocks: p.13-1 to 13-6 *in* Proceedings of the 1977 Geotraverse Workshop, University of Toronto.

Coleman, A.P.

1902: Iron Ranges of Northwestern Ontario; Ontario Bureau of Mines, Annual Report, Volume II, p.128-151.

---

[1] Pertinent papers not referred to in text are included in references.

Collins, W.H.
1907: On Surveys Along the National Transcontinental Railway Location Between Lake Nipigon and Lac Seul; Geological Survey of Canada Summary Report for 1906, p.103-109, Accompanied by Map Number 993, scale 1:253 440.

Covello, L.
1971: The Structure, Stratigraphy, and Petrology of the North End of Abitibi Block Seven, Sturgeon Lake, Ontario; Unpublished B.Sc. Thesis, Lakehead University, Thunder Bay, Ontario, 66p.

Currie, K.L.
1976: The Alkaline Rocks in Canada; Geological Survey of Canada, Bulletin 239, 228p. Accompanied by Map 1369A, scale 1:5 000 000.

Davidson, E.J.
1901: Surveyor's Report of Exploration Survey Party Number 9; p.207-250 *in* Report of the Survey and Exploration of Northern Ontario, 1900.

Davies, J.C., Pryslak, A.P., and Pye, E.G.
1970: Sioux Lookout-Armstrong Sheet, Kenora and Thunder Bay Districts; Ontario Department of Mines, Geological Compilation Series, Map 2169, scale 1:253 440.

Dimroth, E.
1977: Facies Models - 5. Models of Physical Sedimentation of Iron Formation; Geoscience Canada, Volume 4, p.23-30.

Dusanowskyj, T.H.
1977: A Gravity Study of the Sturgeon Lake Metavolcanic Metasedimentary Belt; p.1-5 to 1-10 *in* Proceedings of the 1977 Geotraverse Workshop, University of Toronto.

Dusanowskyj, T.H., and West, G.F.
1976: Gravity Study of the Sturgeon Lake Area; p.56-60 *in* Preceedings of the 1976 Geotraverse Conference, University of Toronto.

Elbers, F.J.
1974: Calc-Alkaline Plutonism, Volcanism, and Related Hydrothermal Mineralization in the Superior Province, Northeastern Manitoba; Manitoba Department of Mines, Resources, and Environment Management Publication.

Ferguson, S.A., Groen, H.A., and Haynes, R.
1971: Gold Deposits of Ontario; Mineral Resources Circular No. 13; Ontario Department of Mines and Northern Affairs, Part 1, 315p.

Fisher, R.V.
1966: Rocks Composed of Volcanic Fragments and Their Classification; Earth Science Review, Volume 1, p.287-292.

Fiske, R.S.
1963a: Subaqueous Pyroclastic Flows in the Ohanapecosh Formation Washington; Geological Society of America Bulletin, Volume 74, Number 4, p.391-406.
1963b: Geology of Mount Rainer National Park, Washington; U.S. Geological Survey Professional Paper, 444, 93p.

Fiske, R.S., and Matasuda, T.
1964: Submarine Equivalents of Ash Flows in the Tokiwa Formation, Japan; American Journal of Science; Volume 262, Number 1, p.76-106.

Franklin, J.M.
1975: Metallogenic Relations at Sturgeon Lake; p.39-1 to 39-25 *in* Proceedings of the 1975 Geotraverse Workshop, University of Toronto.

1976: Role of Laharic Breccia in Genesis of Volcanogenic Massive Sulphide Deposits; p.293-300 *in* Geological Survey of Canada, Report of Activities, Part A, Paper 76-1 A.
1977: Stratigraphic and Chemical Relations, South Sturgeon Lake Area; p.19-1 to 19-5 *in* Proceedings of the 1977 Geotraverse Project, University of Toronto.

Franklin, J.M., Gibb, W.,Tamman, A., and Kerr, B.
1973: The Mattabi Deposit; Canadian Institute of Mining and Metallurgy, Geological Division Annual Field Trip, Guidebook 19p.

Franklin, J.M., Gibb, W., Pauken, K.H., and Severin, P.
1977: Archean Metallogeny and Stratigraphy of the South Sturgeon Lake Area; Mattabi Trip, 23rd Annual Meeting at Institute on Lake Superior Geology, 73p.

Franklin, J.M., Kasarda, J., and Poulsen, K.H.
1975: Petrology and Chemistry of the Alteration Zone of the Mattabi Massive Sulphide Deposit; Economic Geology Volume 70, Number 1, p.63-79.

Friske, P.
1974: The Beidelman Bay Copper Porphyry Deposit; Unpublished B.Sc. Thesis, Lakehead University, Thunder Bay, Ontario, 108p.

Gledhill, T.L.
1924: Geology Along an Eastward Continuation of Niven's 4th Base Line; Ontario Department of Mines, Volume 33, Part 8, p.18-39 (published 1925).

Goodwin, A.L.
1970: Metalogenic Evolution of the Canadian Shield; p.156-162 *in* Geology and Economic Minerals of Canada, Edited by R.J.W. Douglas, Geological Survey of Canada, Economic Report Number 1, 838p.
1972: The Superior Province, p.527-623 *in* Variations in Tectonic Styles in Canada; Edited by R.A. Price, and R.J.W. Douglas; Geological Association of Canada, Special Paper Number 11, 688p.
1973: Archean Iron Formations and Tectonic Basins of the Canadian Shield, Economic Geology, Volume 68, p.915-933.

Gordanier, W.D.
1975: Geochemistry of a Carbonate Breccia Unit in Northwestern Ontario; Unpublished B.Sc. Thesis; University of Ottawa, Ottawa, Ontario, 180p.

Gorman, B.E., Pearce, T.H., and Birkett, T.C.
1978: On the Structure of Archean Greenstone Belts; Precambrian Research, Volume 6, p.23-41.

Graham, A.R.
1930: Sturgeon Lake Gold Area, Districts of Kenora and Thunder Bay; Ontario Department of Mines, Volume 39, Part 2, p.36-50 (published 1931). Accompanied by Map Number 396, scale 1:126 720.

Heinrich, E.Wm.
1966: The Geology of Carbonatites; Rand McNally and Company, Chicago, 555p.

Hinzer, J.C.
1977: Geological and Geochemical Survey of Lyon Lake and Creek Ore Zones, Sturgeon Lake, Northwestern Ontario; Unpublished M.Sc. Thesis, University of Western Ontario, London, Ontario 94p.

Hiscott, R.N.
1974: A Petrochemical and Petrological Investigation of an Archean Volcanic Sequence, Superior Province, Canada; Unpublished B.Sc. Thesis, Brock University, St. Catherines, Ontario.

Hoad, J.S.
1970: Bell Lake Syenite Complex; Unpublished B.Sc. Thesis, University of Waterloo, Waterloo, Ontario, 32p.

Hodgson, C. J., and Lydon, J.W.
1977: Geological Setting of Volcanogenic Massive Sulphide Deposits and Active Hydrothermal Systems; Some Implications for Exploration; Canadian Institute of Mining and Metallurgy Bulletin, Volume 70, Number 786, p.95-106.

Horwood, H.C.
1937a: Geology of the Superior Junction-Sturgeon Lake Area; Ontario Department of Mines, Volume 46, Part 6, p.1-25, (Published 1938). Accompanied by Map 46a, scale 1:126 720.
1937b: Geology at the Darkwater Mine; Ontario Department of Mines, Volume 46, Part 6, p.26-39 (Published 1938).

Irvine, T.N., and Baragar, W.R.A.
1971: A Guide to the Chemical Classification of the Common Volcanic Rocks; Canadian Journal of Earth Sciences, Volume 8, p.523-548.

James, M.L.
1954: Sedimentary Facies of Iron Formations; Economic Geology, Volume 49, p.235-293.

Jensen, L.S.
1976: A New Cation Plot for Classifying Subalkalic Volcanic Rocks; Ontario Division of Mines, Miscellaneous Paper 66, 22p.

Johnston, F.J.
1968: Molybdenum Deposits of Ontario; Ontario Department of Mines, Mineral Resources Circular 7, 98p.

Jones, J.G.
1969: Pillow Lavas as Depth Indicators; American Journal of Science, Volume 261, p.181-195.

Kasarda, J.
1973: Wall Rock Alteration and Trace Element Geochemistry of the Footwall Rocks of the Mattabi Deposit, Sturgeon Lake Area, Ontario; Unpublished B.Sc. Thesis, Lakehead University, Thunder Bay, Ontario, 103p.

Lavin, O.P.
1976: Lithochemical Discrimination Between Mineralized and Unmineralized Cycles of Volcanism in the Sturgeon Lake and Ben Nevis Areas of the Canadian Shield; Unpublished M.Sc. Thesis, Queen's University, Kingston, Ontario, 249p.

Lorrentz, V.
1974: Vesicated Tuffs and Associated Features; Sedimentology, Volume 21, p.273-291.

Lovell, J.D., and Guilbert, J.M.
1974: Variations in Zoning Patterns in Porphyry Ore Deposits; Canadian Institute of Mining and Metallurgy Bulletin, Volume 61, Number 742, p.99-109.

MacGeehan, P.J.
1978: The Geochemistry of Altered Volcanic Rocks at Mattagami, Quebec, A Geothermal Model for Massive Sulphide Genesis; Canadian Journal of Earth Sciences, Volume 15, p.551-570.

Mackasey, W.O., Blackburn, C.E., and Trowell, N.F.
1974: A Regional Approach to the Wabigoon-Quetico Belts and Its Bearing on Exploration in Northwestern Ontario; Ontario Division of Mines, Miscellaneous Paper 58, 30p.

McBirney, A.R.
1963: Factors Governing the Natures of Submarine Volcanism; Bulletin of Volcanology, Volume 2, p.455-469.

McConnell, J.W.
1976: Geochemical Dispension in Wallrocks of Archean Massive Sulphide Deposits; Unpublished M.Sc. Thesis, Queen's University, Kingston, Ontario, 230p.

McInnes, W.
1900: Explorations and Surveys, Rainy River District, Ontario; p.115A-122A *in* Geological Survey of Canada, Annual Report, Volume 12, 1899. Report A, 224p. Accompanied by Map Number 663, scale 1:253 440.
1901: Region Southeast of Lac Seul; p.94a, 94b, *in* Geological Survey of Canada, Summary Report, Volume 14.

Mehnert, K.R.
1968: Migmatites and the Origin of Granitic Rocks; Elsevier Publishing Company, Amsterdam, London, New York, 393p.

Meloche, J.D.
1978: A Look at the Geochemistry of Some Archean Carbonate Rocks from Canada and India; Unpublished B.Sc. Thesis, University of Western Ontario, London, Ontario.

Miller, W.G.
1903: Sturgeon Lake Region; p.82-87, 104, 105 *in* Mines of Northwestern Ontario; Ontario Bureau of Mines, Volume 12, p.73-107.

Moore, E.S.
1911: The Sturgeon Lake Gold Field; Ontario Bureau of Mines, Volume 20, Part 1, p.33-157.

Naldrett, A.J., and Cabri, L.J.
1976: Ultramafic and Related Rocks: Their Classification and Genesis with Special Reference to the Concentration of Nickel Sulphides and Platinum-Group Elements; Economic Geology, Volume 71, p.1131-1158.

Neilson, P.E.
1974: The Geochemistry of the Lyon Lake-Claw Lake Sulphide-Bearing Graphitic Shale, Sturgeon Lake, Ontario; Unpublished B.Sc. Thesis, Lakehead University, Thunder Bay, Ontario, 99p.

Ontario Department of Mines-Geological Survey of Canada
1961a: Watcomb, Kenora District; Ontario Department of Mines - Geological Survey of Canada, Aeromagnetic Map 1127G, scale 1:63 320.
1961b: Bell Lake, Kenora and Thunder Bay Districts; Ontario Department of Mines, Geological Survey of Canada, Aeromagnetic Map 1117G, scale 1:63 320.
1961c: Sturgeon Lake, Thunder Bay District; Ontario Department of Mines - Geological Survey of Canada, Aeromagnetic Map 1118G, scale 1:63 320.
1961d: Seseganaga Lake, Thunder Bay District; Ontario Department of Mines-Geological Survey of Canada, Aeromagnetic Map 1108G, scale 1:63 320.
1976a: Airborne Gamma-Ray Spectrometry Survey, Total Count Contours, Sioux Lookout Sheet, Districts of Kenora and Thunder Bay; Ontario Division of Mines, Preliminary Map P.1115, Geophysical Series, scale 1:250 000.
1976b: Airborne Gamma-Ray Spectrometry Survey, total Count Contours, Ignace Sheet, Districts of Kenora and Thunder Bay; Ontario Division of Mines, Preliminary Map P.1150, Geophysical Series, scale 1:250 000.

Palonen, P.A., and Speed, A.A.
1975a: Beckington Lake Area, NTS 52 J/2E, District of Kenora, Sioux Lookout Data Series; Ontario Division of Mines, Preliminary Map P.1035, scale 1:15 840.

1975b: Fourbay Lake Area, NTS 52J/2W, Districts of Kenora and Thunder Bay, Sioux Lookout Data Series; Ontario Division of Mines, Preliminary Map P.1039, scale 1:15 840.
1975c: Squaw Lake Area, NTS 52J/2E, District of Thunder Bay, Sioux Lookout Data Series; Ontario Division of Mines, Preliminary Map P.1045, scale 1:15 840.
1975d: Press Lake Area, NTS 52G/14W, District of Kenora, Sioux Lookout Data Series; Ontario Division of Mines, Preliminary Map P.1046, scale 1:15 840.
1977: Bell Lake Area, NTS 52G/15W, Districts of Kenora and Thunder Bay, Sioux Lookout Data Series; Ontario Division of Mines, Preliminary Map P.1215, scale 1:15 840.

Palonen, P.H.,, Speed, A.A., and King, H.L.
1976: Quest Lake Area, NTS 52G/15E, District of Thunder Bay, Sioux Lookout Data Series; Ontario Division of Mines, Preliminary Map P.1079, scale 1:15 840.

Pettijohn, F.J.
1937: Early Precambrian Geology and Correlational Problems of the Northern Subprovince of the Lake Superior Region; Geological Society of America Bulletin, Volume 48, p.153-202.

Prest, V.K.
1970: Quaternary Geology of Canada; p.616-764 *in* Geological Survey of Canada; Economic Geology Report 1 (5th Edition).

Rodgers, D.P.
1964: Geology of the Metionga Lake Area, Districts of Thunder Bay and Kenora; Ontario Department of Mines, Geological Report 24, 53p. Accompanied by Map Number 2044 (East Half) and Map Number 2044 (West Half), scale 1:63 360.

Sage, R.P., Breaks, F.W., Stott, G.M., and McWilliams, G.
1973: Operation Ignace-Armstrong, Pashkokogan-Caribou Lakes Sheet; Ontario Division of Mines, Preliminary Map P.962, Geological Series, scale 1:126 720.

Schwerdtner, W.M.
1976: Crescent-Shaped Granitic Bodies in the Scotch Lakes Area, Wabigoon Subprovince; p.7-1 to 7-22 *in* Proceedings of the 1976 Geotraverse Workshop, University of Toronto.

Schwerdtner, W.M., and Sutcliffe, R.H.
1978: Structure and Lithology of Two Archean Granitoid Complexes, Ontario; Geological Association of Canada-Mineralogical Association of Canada, Geological Society of America Abstracts, 1978 Joint Annual Meeting, Toronto, Ontario, p.488.

Shegelski, R.J.
1975: Geology and Geochemistry of Iron Formations and Their Host Rocks in the Savant Lake-Sturgeon Lake Greenstone Belts; p.34-1 to 34-21 *in* Proceedings of the 1975 Geotraverse Workshop, University of Toronto.
1976: The Geology and Geochemistry of Archean Iron Formations and Their Relation to Reconstructed Terrains in the Sturgeon and Savant Lakes Greenstone Belts; p.29-1 to 29-22 *in* Proceedings of the 1976 Geotraverse Workshop, University of Toronto.
1978: Stratigraphy and Geochemistry of Archean Iron Formations in the Sturgeon Lake-Savant Lake Greenstone Terrain, Northwestern Ontario; Unpublished Ph.D. Thesis, University of Toronto, Toronto, Ontario, 251p.

Shegelski, R.J., and Bell, R.T.
1976: Coarse Clastic Facies of the Savant Lake and Sturgeon Lake Greenstone Belts; p.28-1 to 28-25 *in* Proceedings of the 1976 Geotraverse Workshop, University of Toronto.

Skinner, R.
1969: Geology of the Sioux Lookout Map-Area, Ontario, a Part of the Superior Province of the Precambrian Shield; Geological Survey of Canada, Paper 68-45, 10p. Accompanied by Map 14-1968, scale 1:253 440.

Sopuck, V.J.
1977: A Lithogeochemical Approach in the Search for Areas of Felsic Volcanic Rocks Associated with Mineralization in the Canadian Shield; Unpublished Ph.D. Thesis, Queen's University, Kingston, Ontario, 296p.

Sorenson, H.
1974: The Alkaline Rocks; Edited by H. Sorenson, John Wiley and Sons Incorporated, New York, 622p.

Spence, de-Rosen, A.F.
1976: Stratigraphy, Development and Petrogenesis of the Central Noranda Volcanic Pile, Noranda, Quebec; Unpublished Ph.D. Thesis, University of Toronto, Toronto, Ontario.

Sutcliffe, R.H.
1977: Geology and Emplacement of the Jackfish Lake Pluton, A Major Intrusion in the Rainy Lake Dome; p.25-1 to 25-13 *in* Proceedings of the 1977 Geotraverse Workshop, University of Toronto.
1978: Origin of Archean Crescentric Granitoids with Mafic Xenoliths, Ontario; Geological Assocation of Canada-Mineralogical Association of Canada-Geological Society of America Abstracts, 1978 Annual Meeting, Toronto, Ontario, p.501.

Szewczyk, Z.J.
1974: A Gravity Study of an Archean Granitic Area North of Ignace, Ontario; Unpublished M.Sc. Thesis, University of Toronto, Toronto, Ontario,87p.

Szewczyk, Z.J., and West, G.F.
1977: Gravity Study of an Archean Granitic Area Northwest of Ignace, Ontario; p.1-3 to 1-4 *in* Proceedings of the 1977 Geotraverse Workshop, University of Toronto.

Tanton, T.L.
1940: Watcomb, Kenora, and Rainy River Districts, Ontario; Geological Survey of Canada. Map 557A, scale 1:253 440.

Trowell, N.F.
1970: Geology of the Watcomb Area, District of Kenora; Ontario Department of Mines and Northern Affairs, Geological Report 88, 28p. Accompanied by Map 2209, scale 1:31 680.
1974a: Geology of the Bell Lake-Sturgeon Lake Area, Districts of Kenora and Thunder Bay; Ontario Division of Mines, Geological Report 114, 67p. Accompanied by Maps 2268, 2269, scale 1:31 680.
1974b: Geology of the Glitter Lake Area; District of Thunder Bay, Ontario Division of Mines, Geological Report 120, 31p. Accompanied by Map 2284, scale 1:31 680.
1974c: An Unusual Carbonate Breccia Unit at Sturgeon Lake, Northwestern Ontario; Abstract, p.34-35 *in* Program, Abstracts, and Field Guides for 20th Annual Meeting of the Institute on Lake Superior Geology (Edited by P.E. Giblin, G. Bennett, E.J. Leahy), Sault Ste. Marie, Ontario, 147p.
1976: Geology of the Quest Lake Area, Districts of Kenora and Thunder Bay; Ontario Division of Mines, Geological Report 154, 60p. Accompanied by Map 2335, scale 1:31 680.
1977: Geology of the Squaw Lake-Sturgeon Lake Area, District of Thunder Bay; Ontario Geological Survey, Open File Report 5225, 230p. Accompanied by 14 Tables, 58 Photos (xerox copies), 7 Figures, and 4 Maps.
1978: Geology of the Sturgeon Lake-Chevrier Township Area, District of Thunder Bay; Ontario Division of Mines, Open File Report 5250, 97p. Accompanied by 7 Tables, 5 Figures, 9 Photos (xerox copies), and 1 Map.

Trowell, N.F., Sage, R.P., Wright, W., Chamois, P., and Higgins, C.
1979: Sturgeon Narrows and Squaw Lake Alkalic Rock Complexes, District of Thunder Bay; Ontario Geological Survey Preliminary Map P.2223, Geological Series, scale 1:15 840 or 1 inch to ¼ mile.

Turner, F.J.
1968: Metamorphic Petrology, Mineralogical and Field Aspects; McGraw-Hill Book Co., New York, 403p.

Vokes, F.M.
1963: Molybdenum Deposits of Canada; Geological Survey of Canada, Economic Geology Report Number 20, 332p. Accompanied by 3 sketch maps.

Walker, R.G.
1975: Generalized Facies Models for Resedimented Conglomerates of Turbidite Association; Geological Society of America, Bulletin, Volume 86.

Wilson, H.D.B., and Morrice, M.G.
1974: Archean Volcanic Sequence; Principal Structures and Textures; Characteristics of the Volcanic Group; Geochemistry of the Volcanic Sequence; Nature of Subvolcanic Intrusions in the Volcanic Sequence; Stratigraphic Mapping of Greenstone Belts; Sections 3-7; 9; p.58060, and 84085 *in* Centre for Precambrian Studies, University of Manitoba, Annual Report 1974, Part 2,253p.

Wilson, H.D.B., Morrice, M.G., and Ziehlke, D.V.
1974: Archean Continents; Geoscience Canada, Volume 1, p.12-20.

Young, G.M.
1967: Sedimentology of Lower Visean Rocks in the Western Part of the Gallina and Donegal Synclines, Northwestern Ireland; Unpublished Ph.D. Thesis, University of Glasgow, Scotland, 204p.

Zalnierinunas, R.V.
1978: A Study of Four Ultramafic Intrusive Bodies Found North of Post Lake, Northwestern Ontario; Unpublished B.Sc. Thesis, Queen's University, Kingston, Ontario, 34p.

INDEX

PAGE
Abitibi Paper Co. Ltd. 3
Add Lake 46
Agmatite breccia 24,26
Alkalic province 33
Allanite 23
Alteration effects:
  Petrochemical studies 47
Amphibolitic mafic metavolcanics and metasediments 19
Amygdaloidal flows 44,63,66
Analyses, chemical:
  Discussion of 72
See also: Assays.
Andalusite 11
Anderson Lake 82
Andesite 67
Anthophyllite 9
Anticlinal structures 78
Aplite dikes 19,26,28
Arsenopyrite 44
Assays:
  Copper 5,83
  Gold 5,83
  Lead 5
  Silver 5
  Zinc 5
See also: Chemical analyses.
Ash tuff 42
Autoclastic unit 52

Barge Lake 13,46,71,72
Basalt, tholeiitic 54,55
Base-metal massive sulphide deposits: table 4
Batholithic emplacement 38
Beckington Lake 24,67,78
Beckington Lake East Cycle (Northeast Arm Assemblage) 66,67
  Formations 66
Beckington Lake West Cycle (Northeast Arm Assemblage) 66,67,68
  Environment of formation 66
  Formations 66
Beidelman Bay 81
Beidelman Bay Pluton 5,15,18, 40,41,81,83
Bell Creek 43
Bell Lake 20,37
Bell Lake Alkalic Complex . . 31,32,33,37
Biotite-trondhjemite sill 50
Boucher Tp. 10
Breccia 83
  Agmatite 24,26
  Autoclastic 9-10
  Carbonate 83
  Hyaloclastic 9

PAGE
  Intrusive 16,37
  Pillow 63,70
  Pyroclastic 10,41,42,70
Byline Lake 24,27

Calc-alkalic rhyolite 67
Calc-alkalic rocks 47
Can-Con Enterprises & Exploration Ltd. . 4
Cancrinite 35
Carbonate breccia 83
Cataclastic texture 79
Central Sturgeon Lake Assemblage . . 25,71
Central Sturgeon-Post Lake Cycle (Sturgeon Lake Assemblage)
  Environment of formation 69-73
  Formations 69
Chalcopyrite 3,5,9,18,30,44
Chemical analyses, discussion of 72
See also: Assays.
Chilveston Lake 83
Chloritoid 9,10
Chromite 72
Chromium 73
Clasts:
  In debris flows 46
  In lapilli-tuff 51
Claw Lake Cycle (South Sturgeon Lake Assemblage) 39,47,48
  Environment of formation 42
  Formations 42-43
Claw Lake-Lyon Lake Graphite Sulphide Formation 44
Cobalt 73
Cobb Bay 52
Conglomerate 52,71
Contacts:
  Bell Lake Alkalic Complex-Southern Granitic Complex 37
  Lower mafic metavolcanic flows — upper intermediate to felsic pyroclastic rocks 13
  Western Granitic Complex-volcano-sedimentary belt 19
Copper 3,5,18,73,79,83
  Assays 5,83
  Systems, porphyry 18
Cordierite 10
Couture Lake 30
Coveney Island 63,82
Crystal-lithic tuff 45
Crystal tuff 62

Dacite 56,67
Darkwater Lake Cycle (South Sturgeon Lake Assemblage) 10,15,47,48,79
  Formations 40-42

PAGE

- Darkwater Lake Mine. . . 3,15,18,47,81,83
- Debris flows. 46
  - Subaqueous 51
- Deweylite .72
- Dikes 12,24,30,40,53,63,71,72,73,83
  - Anorthositic. 62
  - Aplite 19,26,28
  - Diorite 26
  - Feldspar porphyry. 51
  - Gabbro 37
  - Gabbro diorite 50-62
  - Granodiorite. 24,26
  - Granodiorite-trondhjemite 31
  - Intermediate volcanic. 67
  - Lamprophyre 37
  - Mafic synvolcanic 50
  - Mafic volcanic. 51
  - Pegmatite. 19,28
  - Pegmatitic nepheline syenite 36
  - Pyroxenite. 37
  - Syenite 26,36
  - Synvolcanic 44
  - Trondjhemite 3,51
  - Ultramafic 71
  - Volcanic 45
- Diorite .40
  - Dikes 26

- East Bay (Sturgeon Lake) . . . 11,39,71,82
- East Bay sequence (metasediments) . . . 11
- East Bay-Sturgeon Narrows metasediments 70
- Eastern Batholith Complex 21,37
- Epizonal (Subvolcanic) Intrusion 18

- Falconbridge Copper Ltd. 5
- Falconbridge Nickel Mines Ltd. 5
- Faults 78,79
  - Mountain Island Bay 70,79
  - Savant Lake 79
- Feldspar porphyry dikes. 51
- Felsic flows 66
- Felsic tuff 71
- Flows:
  - Amygdaloidal 9,42,44,63,66
  - Debris. 10,46,51
  - Felsic 66
  - Intermediate. 67
  - Mafic 41,47,50,53,65,67,70
  - Massive 9,42,63,66
  - Pillowed 9,42,63,66,70
  - Porphyritic. 9,42,50,52,66
  - Pumice 41
  - Pyroclastic 10,51
  - Turbidity. 10
  - Vesicular 9
- Fluorite. 3,5,23,35,36,79,82
- Folds, kink. 78,79
- Fourbay Lake. 19

PAGE

- Fourbay Lake Cycle (North Sturgeon Lake Assemblage). 50,51,52, 54,55,61,62,66
  - Environment of formation 50-51
  - Formations 50

- Gabbro .40,72
  - Dikes .37
- Gabbro-diorite 67
  - Dikes 50,62
    - Anorthositic. 62
  - Intrusions 53,62
  - Sills 50,62
    - Anorthositic. 62
- Galena. .3,30
- Garnet. 9,10,11,33,35,36
- Gold. 3,18,39,79,81,82,83
  - Assays. 5,83
  - *In* quartz veins 3,30
- Gold producer, past: table. 4
- Goodman Lake. 31
- Goodman Lake Pluton 23
- Granite Bay Pluton 24,25,28,70,78
- Granodiorite. . . . 16,18,19,23,26,27,30,31
  - Dikes 24,26
  - Sills 24
- Granodiorite-trondhjemite dikes. 31
- Graphite Sulphide Formation, Claw Lake-Lyon Lake 44
- Graphitic ironstone 12
- Graphitic shale 42,43,44

- Handcuff Lake 52
- Handy Lake Volcanics 66,80
- Harold Lake. 79
- Harris Lake 79
- Hematite 11,24,72

- Intermediate flows. 67
- Intrabelt Granodiorite-Trondhjemite Plutons 28
- Intrusions:
  - Anorthositic. 12
  - Epizonal 17
  - Gabbro-diorite 53,62
  - Mafic 12
  - Syenite-monzonite-granodiorite 39
- Intrusive breccia 16,37
- Intrusive rocks:
  - Division of. 13-14
- Iron 3,5,79,82
- Ironstone. .81
  - Graphitic. 12
  - Quartz-magnetite. 5,12,46
  - Sulphide 3,12

- Jackfish-Weller Lake Pluton. 21
- Jigger Lake-Valora Lake Pluton 30
- Jumping Lake-Six Mile Lake Cycle (North

PAGE

Sturgeon Lake Assemblage) . . 50-55,62,63,69
  Environment of formation 51-53
  Formations 51

King, Peter 3
King Bay 30
King Bay Gold Occurrence 83
King Lake 31
Kink folds 78,79
Kyanite 10

Lamprophyre dikes 37
Lapilli-tuff 41,62,63
Lead 73,79
  Assay 5
Lineaments 78,79
Lithologic units; table 6
Lyon Lake 43
Lyon Lake Cycle (South Sturgeon Lake Assemblage) . . 39,43-44,47,48,79
  Environment of formation 43-44
  Formations 43-47
Lyon Lake ore zone 79,80

Mafic flows 47,50,53,65,67,70
Mafic metavolcanics and metasediments, amphibolitic 19
Mafic synvolcanic dikes 50
Mafic volcanic dikes 51
Magnetite 72
Marcasite 30
Massive flows 63,66
Mattabi 43
Mattabi Mine 42,43
Mattabi Mines Ltd. 3,4,41,80
Mattabi orezone 80
Mattagami Lake Mines Ltd. 3,4
Metamorphic mineral assemblage 10
Metasediments:
  Amphibolitic mafic 19
  East Bay-Sturgeon Narrows 70
  Quest Lake-Princess Lake 70
Metavolcanics:
  Amphibolitic mafic 19
  Classification of 8
Mineral assemblages:
  Metamorphic 10
  Of the metasediments 11
Mineralization:
  Beidelman Bay Pluton 18
  Shanty Lake Pluton 18
Minerals, nickel sulphide 72
Molybdenite 18,81
Molybdenum 3,5,18,79,81,83
Monzonite 36,37
Morgan Island 62
Morgan Island Section (Northeast Arm Assemblage) 64,66,83
  Formations 61
Mountain Island 13,70-73,78
Mountain Island Bay 24
Mountain Island Bay Fault 70,79
Mountain Island Bay Pluton 25,27,28,70,78

N.B.U. Mines Ltd. 5
Nepheline alteration products 35
Nepheline syenite 36
New Brunswick Uranium Metals and Mining Ltd. 5
New Santiago Mines Ltd. 82
Nickel 73,83
Nickel sulphide minerals 72
North Arm Cycle (Northeast Arm Assemblage) 61,66
  Formations 61
North Arm of Sturgeon Lake 19,27,30
North Arm Pluton 27,29,30,39,83
Northeast Arm Assemblage . . 12,39,65,83
  Beckington Road Section:
    Chemical data 67
    Volcanic cycles 66
  Chemical data 64
  Morgan Island Section 64,66,83
    Formations 61
Northeast Arm Cycle (Northeast Arm Assemblage) 61-65
  Environment of formation 62-63
  Formations 61
Northeast Arm (Sturgeon Lake) . . . 10,30,78,79,81
North Shore Cycle 53,66
North Sturgeon Lake Assemblage . . 12,47,49,51,53,55,61,67,69,71,78
  AFM plot: figure 54
  Cation plot: figures 55,56
  Petrochemistry 54
  Volcanic cycles 49
Northwestern Batholithic Complex . . 29,39
Northwestern Granitic Complex 30

Olivine 36,72,73
Ouilette Lake 10,62

Palladium 73
Pebble conglomerate 62
Pegmatite 26
  Dikes 19,28
Penassi Lake 28,29
Penassi Lake Pluton 27,28,29,39
Peridotites, serpentinized 72
Pike Lake Pluton 40
Pillow breccia 51,63,70
Pillowed flows 63,66,70
Pillows 62,70
  Porphyritic 66

PAGE

- Plutons:
  - Models for emplacement . . . 20-21
- Porphyritic flows . . . 50,52,66
- Porphyry copper systems . . . 18
- Post Lake . . . 13,46,70,71,78
- Post Lake-Mountain Island Cycle (Sturgeon Lake Assemblage) . . . 73
- Princess Lake . . . 11,46,71,78
- Pumice flows . . . 41
- Pumisceous tuff . . . 42
- Pyrite . . . 18,30,72
- Pyroclastic breccia . . . 10,41,42,70
- Pyroclastic flows . . . 10
  - Subaqueous . . . 51
- Pyroclastic rocks, subdivision; basis of . . . 9
- Pyroxenite . . . 37
  - Dikes . . . 37
- Pyrrhotite . . . 72

- Quartz diorite . . . 16
- Quartz-magnetite ironstone . 5,12,46-47,81
- Quartz monzonite . . . 30,31
- Quartz veins . . . 17,18,81,83
  - Gold-bearing . . . 3,30
- Quest Lake . . . 11,46,78,81
- Quest Lake-Princess Lake metasediments . . . 70

- Rhodium . . . 73
- Rhyolite . . . 56
  - Calc-alkalic . . . 67
- Richan Lake Cycle . . . 66,67,68
- Rock classification system . . . 7
  - Metavolcanics . . . 8

- St. Anthony Mine . . . 3,30,39,81,82
- St. Anthony Pluton . . . 19,27,30,39,82
- Saunders Lake . . . 27
- Saunders Lake Pluton . . . 24,27
- Savant Lake . . . 66,79,80
- Savant Lake (town) . . . 83
- Savant Lake Fault . . . 79
- Seaton Island . . . 82
- Sedimentary structures . . . 10
- Serpentinized peridotites . . . 72
- Shanty Lake . . . 18,81
- Shanty Lake Pluton . . . 18,83
- Siderite . . . 30
- Sillimanite . . . 10
- Sills . . . 12,40,53,63
  - Biotite trondhjemite . . . 50
  - Gabbro-diorite . . . 50,62
    - Anorthositic . . . 62
  - Granodiorite . . . 24
- Siltstone . . . 50
- Silver . . . 3,79,81,82

PAGE

  - Assay . . . 5
- Six Mile Lake . . . 8,10,52
- Southern Batholithic Complex . . . 30,37
  - Zones . . . 20
- South Shore Cycle (South Sturgeon Lake Assemblage) . . . 10,40,47,49
  - Environment of formation . . . 44-45
  - Formations . . . 44
- South Sturgeon Lake Assemblage . 9,10,12, 20,45,47,49,64,65,70,71, 78,79,80 81,83
  - AFM plot: figure . . . 48
  - Volcanic cycles . . . 39
- South Sturgeon Lake Strato-volcano . . . 46
- Sphalerite . . . 3,30,44
- Sphene . . . 11,18,24,30,31,35,36
- Squaw Lake Complex . . . 31,32,33
  - Compositional groupings . . . 36
- Squaw Lake Cycle (Northeast Arm Assemblage) . . . 61,64,65
  - Environment of formation . . . 63
  - Formations . . . 63
- Staurolite . . . 10,11
- Stilpnomelane . . . 10
- Strato-volcano . . . 45
  - South Sturgeon Lake . . . 46
- Sturgeon Lake Assemblage . . . 13,39,56, 69,70,71,73
- Sturgeon Lake Belt . . . 46
- Sturgeon Lake Metavolcanic-Metasedimentary Belt, Subdivision of . . . 7
- Sturgeon Lake Mines Ltd. . . . 4,5,80
- Sturgeon Lake Volcano-Sedimentary Belt . . . 19,22,24,27
- Sturgeon Narrows . . . 71,78,82
- Sturgeon Narrows Alkalic Complex. 31,32, 33,36,78,82
  - Feldspathic leucosyenite . . . 35
  - Outer syenite . . . 35
  - Zones . . . 35
- Sturgeon Narrows Cataclastic Zone. . . 33, 35,45,78,82
- Sturgeon Narrows metasedimentary sequence . . . 11
- Sulphide ironstone . . . 3
- *See:* Chalcopyrite; Galena; Molybdenite; Molybdenum; Nickel sulphide; Pyrite; Pyrrhotite; Spherulite.
- Sulphidic ironstone . . . 12,81
- Superior Province . . . 7
- Synclinal structure . . . 78
- Syenite . . . 36
  - Dikes . . . 26,36
    - Pegmatitic nepheline . . . 36
- Syenodiorite . . . 35
- Syeno-monzonite . . . 36

PAGE

Synvolcanic dikes 44

Tension gashes 45
Textures:
  Cataclastic 79
  Equigranular. 31
  In gabbro. 72
  In intrusive rocks. 12,13
  In metavolcanics 8,10
  Myrmekitic 15
  Pegmatoid 32
  Porphyritic. 31
Tholeiitic basalt 54,55
Tholeiitic rocks. 47
Tourmaline 11,15,35
Trace element data
  for Sn and Pb 73
Trondhjemite 19
  Dikes .3,51
Tuff 41,63
  Ash. 42
  Crystal 62
  Crystal-lithic. 45
  Felsic 43,71
  Mafic 44
  Massive 42
  Pumiceous 42
  Vesiculated 42
Tuff-breccia 10,62,71

Ultramafic dikes 71
Uranium, mineralization 79,82

Valora Lake-Jigger Lake Pluton 30
Vanessa Lake 19,24,78
Vanessa Lake Cycle (Northeast Arm
    Assemblage). 61
  Formations 64
Vanessa Lake Pluton 21,22
Veins, quartz 17,18,81,83
  Gold-bearing. 3,30
Vesiculated tuff 42
Vista Lake 78,81
Vista Lake Complex. 21,22,31,78
Vista Lake Cycle (Northeast Arm
    Assemblage). 61
  Environment of formation 63
  Formations 63
Volcanic breccia unit 52
Volcanic centres 70
Volcanic cycle; definition and
    subdivision of. 7
Volcanic dikes 45
  Intermediate. 67
Volcanics, Handy Lake. 66
Volcano-Sedimentary Belt, Sturgeon
    Lake. 19
  Contact with Western Granitic
    Complex 19

Wabigoon Subprovince. 7
Wacke. 50
Wacke-siltstone. 63
Wahl, W. G., Ltd. property 82
Western Granitic Complex. 50
  Contact with Sturgeon Lake volcano-
    sedimentary belt 19
Willet Lake. 46

Zinc 3,73,79
  Assay 5
Zircon. 11,23,24,30